Chapter 17

SOFT TISSUE INJURIES AND REPAIR

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INTRODUCTION

Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) have changed the perspective on treating acute injuries to the face and neck. Injuries encountered during both wars reflect a different wounding pattern than that encountered in stateside trauma centers. Given the use by enemy combatants of high velocity weaponry such as the improvised explosive device (IED), mortar round, and high velocity rifles, a higher incidence of facial wounds has been reported. The introduction of modern thoracoabdominal reinforced body armor has significantly decreased the incidence of injury to the chest and abdomen, while facial injuries have increased (both in total and in relation to abdominal and chest injuries) over this same period. The incidence of facial injury in relation to total battle injury ranges from 9% to 19%. Penetrating explosive fragments account for the majority of facial[1] and eye[2–4] injuries. This chapter will present the US combat experience with soft tissue injuries in the acute setting and modalities of repair for combat facial wounds.

There is currently no agreed-upon method of describing the location of either civilian or military penetrating facial wounds. Dolin et al[5] designated entry zones in the face as zone A, representing the lateral face; zone B, the anterior maxilla; and zone C, the anterior mandible. This system does not include the area above the supraorbital margin as a facial injury. Chen et al[6] divided penetrating facial wounds into categories of the mandibular and midface regions, excluding the upper third of the face, where injuries were deemed intracranial wounds.

Surface wound mapping is a technique that uses the topographical location of facial wounds to help plan their repair. In a study by Breeze et al of hospital and postmortem records for 1,187 United Kingdom service members (with both battle injuries and nonbattle trauma) during the period January 1, 2005, to December 31, 2009,[1] the investigators found 391 (33%) had penetrating injuries to the face or eye, with 113 of those (10% of the total) having sustained their injuries in battle. The lower third of the face was most commonly injured (60%), followed by the upper third (24%). Combat eye protection reduced facial injuries as a whole (bone and soft tissue) by 15% ($P < 0.01$).

WOUND MANAGEMENT

Wound debridement in the setting of acute facial injuries is controversial. The combat experience in Afghanistan predates US involvement. Over the period 1981 to 1985, doctors Shvyrkov and Yanushevich treated 1,486 patients with facial gunshot wounds sustained in combat in Afghanistan. Weapons including the M-16 and AK-47 rifles and Kalashnikov submachine guns are used extensively in the Afghanistan theater due to the prolonged conflict in the region. The management of 502 isolated soft tissue injuries, with the goal of tissue sparing, led to a high rate of complications (47.6%). Therefore, the doctors adopted a radical primary surgical debridement (RPSD) approach, which led to a decrease in wound infection and breakdown by a factor of 10.[7]

Recently, the Joint Facial and Invasive Neck Trauma study revealed that the most common mechanisms of injury during OIF and OEF were penetrating (49.1%), followed by blunt (25.7%), blast (24.2%), and other/unknown/burn injuries (1%). In addition, the most common soft injury sites were the face/cheek (48%), neck/larynx/trachea (17%), and mouth/lip (12%).[8]

Penetrating missile trauma can be a low or high velocity injury. The wounding capacity of a missile is directly proportional to its velocity. Low energy wounds are those caused by a projectile traveling at a velocity less than the speed of sound, which results in the laceration of soft tissue.[9] Injury to the underlying bone is often due to the missile itself. In contrast, high energy wounds are produced by missiles traveling faster than the speed of sound. Large amounts of energy are transferred to the tissues of the body, resulting in perforating or avulsion wounds to the soft tissue, with disruption of cortical bone. The high energy accompanying high velocity missiles often causes disruption of wounds beyond the entry and exit patterns found on initial survey.

Blunt injuries that cause soft tissue injury include stab injuries that don't penetrate the platysma, accidental penetration by a foreign object, and secondary injuries from falls. Stab injuries usually result in lesser degrees of injury than missile wounds, and by nature are categorized as low velocity. The rate of explorations with negative findings associated with mandatory surgical exploration of all stab injuries of the neck is 10% higher than the rate of elective explorations with negative findings in missile injuries.[9]

Accidental injuries resulting in the penetration of the platysma by a foreign object are mainly caused by environmental factors. Injury from metal, glass, or wood can result in collateral tissue damage only

when penetrating the platysma. These injuries should be evaluated with radiography to determine if foreign bodies remain in the neck.

Penetrating neck wounds can cause injury to one or more of the major organ systems of the neck, including the great vessels, larynx and trachea, esophagus, and spinal column. Injuries to the vascular system occur in 25% to 56% of penetrating neck wounds, and injuries to the carotid and subclavian arteries are the most common cause of mortality. Approximately 20% to 30% of penetrating neck wounds result in laryngeal, tracheal, or esophageal injuries.[9] More often, smaller bleeding vessels cause significant mortality and are more commonly injured from penetrating trauma.

AIRWAY MANAGEMENT

Advanced Trauma Life Support (ATLS) guidelines established by the American College of Surgeons are paramount in evaluating patients with soft tissue injuries.[10] Rather than focusing on a soft tissue injury to the face, neck, or eye, the provider must instead begin with a rapid assessment of the airway, breathing, and circulation. Airway management in a patient with a significant soft tissue injury or penetrating injury may be difficult. Complicating factors including hematoma, whether expansive or space occupying, subcutaneous emphysema, hoarseness, stridor, respiratory distress, hemoptysis, and hemodynamic instability; all suggest injury to the airway and/or vasculature.

Airway management in patients with extensive soft tissue injury must accompany an evaluation of the oropharyngeal and laryngotracheal complex. Intubation may not be feasible in patients with significant swelling, loss of normal nasal and oral anatomy, or complicating factors. Therefore, awake tracheotomy in the operative setting and in a controlled environment may be the safest approach. Indications include significant airway swelling, previous failed intubation attempts, the complicating factors as previously described, and extensive loss of facial and neck anatomy secondary to high velocity injuries.

After airway control by either intubation or tracheotomy, bleeding and circulation should be addressed. A secondary survey is conducted after the patient is initially stabilized, and any associated injuries are documented. Often a team approach expedites the evaluation of the patient. Details about the mechanism of injury should be documented; specifically, what type of projectile; whether the injury was due to a mortar, missile, IED, or bullet; the distance between the gun and the victim; caliber of weapon; and number of shots fired. Often, a complete physical examination is possible only in the operative setting. In a controlled environment, the extent of soft tissue injury, associated bony discontinuity, injury to vital structures such as the airway and eye, and involvement with the nasopharyngeal, oropharyngeal, and hypopharyngeal tracts can be evaluated. Direct laryngoscopy is often undertaken, and evaluation of the esophagus and the trachea via formal rigid or flexible esophagoscopy and bronchoscopy gives the surgeon an idea of compounding and associated injuries. Many factors must be considered during the repair of soft tissue wounds in the combat setting. Relevant issues include the need for tissue preservation, aeroevacuation of NATO combatants, and the ability to immediately repair certain injuries with the hope of timely return to duty in theater. The following are indications for immediate soft tissue repair:

- A soft tissue wound exposes bone or an associated fracture.
- Definitive repair of the soft tissue wound or fracture would not delay the evacuation of the soldier.
- Treatment of the soft tissue injury would allow the soldier to remain in theater.[11]

WOUND INFECTION MANAGEMENT

Controversy currently exists over whether to perform in-theater fracture repair on wounded NATO forces versus treating these fractures in their home country. Questions arising as to whether repair was deemed safe in theater as well as the incidence of wound infection were evaluated by Lopez et al.[11] Using the three criteria listed above, a total of 175 patients (85% of soldiers in this study) were operated on for traumatic injuries. The majority were soft tissue injuries, with 52 of these patients requiring open reduction and internal fixation (ORIF) of a facial fracture. Of the 52 patients who underwent an ORIF, 17 were American military personnel. Of the 17 American patients who were definitively treated for their fractures in theater, 16 were contacted or followed up on the global military medical database (part of the Joint Theater Trauma Registry). None of these patients developed an *Acinetobacter baumannii* or polymicrobial infection, and only one patient required removal of a facial plate.

Antibiotics should be considered in the treatment of high velocity facial wounds. There are currently no studies identifying the microbiology of combat

wounds from OIF or OEF. However, in a study of 564 jaw fractures evacuated to a level IV hospital in the Philippines during the Vietnam war, 31 patients with postoperative infections were described. Daily cultures were performed on all patients. Pseudomonas species and *Klebsiella* species were cultured before the first surgery in 100% of patients. *Staphylococcus aureus*, *Escherichia coli*, and fungi (likely *Candida* species) were also reported, but rates of infection for these pathogens are not included.[12] Another study from Lebanon noted *Proteus mirabilis*, *Bacteroides fragilis*, and *Peptococcus* and *Peptostreptococcus* species in maxillofacial wound infections.[12] Based on these two studies, perioperative and empiric antibiotics against these pathogens to prevent or initially treat infection might be warranted, but the evidence is very poor.[13,14] Copious irrigation with debridement of nonviable tissue is recommended for any facial wound. Pan cultures should be taken and fragments removed. Within established ATLS protocol, ultrasound and computed tomography (CT) scans for fragments is recommended, with priority given to airway and hemorrhage control.

In mass casualty responses to injured NATO soldiers and the local national population, ATLS protocols are implemented to maintain priority inpatient management. Injured NATO members should undergo a rigorous schedule of wound care consisting of irrigation, debridement of fragments, and control of hemorrhage as they progress from Role 1 to Role 3 facilities. Drains are commonly used for open contaminated wounds. In the presence of a mass casualty event where resources are limited, hemorrhage control with drain management may be necessary. When time permits, more formal wound debridement, fracture management, and closure can be conducted at the Role 3 hospital when the criteria listed above are met. The algorithm for NATO members differs from that of local Afghan care. It is common for extensive wounds in local Afghans to require long hospitalization periods at Role 3 facilities, often over 2 weeks with severe wounds. During this time, burn management and antimicrobial therapy are maximized. Given the limited time and space resources, free tissue transfer should be performed judiciously (the indications and management of free tissue transfer are described in Chapter 27, Complex Head and Neck Reconstruction in Theater). Due to the low compliance rate for follow-up, sutures should be removed prior to discharge or absorbable sutures should be used.

Soft tissue repair necessitates several steps in wound debridement prior to closure. Bone protrusion through an open wound increases the incidence of infection, and immediate repair is warranted. In these scenarios, a conservative plan for tissue preservation is warranted. The Joint Theater Trauma Registry includes reported data on coordinated sites of wound debridement and potential repair in patients presenting to the Role 3 hospital during OIF and OEF. By the time the patient presents to a Role 3 hospital, facial wounds may have been conservatively managed with major vessels being ligated or facial compression present for vascular control. Rapid primary surgical debridement may lead to a decrease in wound infection and breakdown, but the judicious use of wound care principles incorporating conservative repair and, for significant high explosive injury, delayed definitive repair is warranted. Although a patient with subquadrant loss of skin and soft tissue may do well with immediate repair, another patient with multiple zones of skin loss and soft tissue and bony injury may require frequent debridement and delayed radical debridement and flap repair.

Case study 17-1 demonstrates the case for immediate soft tissue repair. The soldier suffered subquadrant loss of zone C with right lower lip, chin, and cheek soft tissue loss and mandibular fracture. Immediate repair was performed after control of hemorrhage and bony ORIF of the mandible. No infection or wound loss was experienced.

Given the abundant vascular supply of the face, skin and soft tissue loss involving one specific zone can be bridged with normal tissue from another zone in the acute setting (Case study 17-2). When more than one zone of injury is involved with compromise to the local vasculature, local wound coverage is important to prevent infection, ensure closure of fractures, and prevent oral-cutaneous fistulas. With extensive skin loss, primary closure may not be possible. The surgeon should preserve as much viable tissue as possible and allow for wound demarcation in high velocity explosive injuries. In such wounds, a staged approach is recommended (Case study 17-3).

SUMMARY

The treatment of acute facial combat injuries requires a thoughtful and judicious approach. Relevant factors include the extent of involvement, impact on the bony skeleton and overlying soft tissue, and condition of the facial vasculature. A zone-differentiated approach is warranted, with immediate repair for isolated zonal injuries by way of conservative debridement and closure or local flaps. For more extensive injuries, local soft tissue coverage followed by daily wound care will allow for demarcation of injuries that can be repaired in the delayed setting with a regional or free musculocutaneous flap.

CASE PRESENTATIONS

Case Study 17-1

Presentation

A 22-year-old male US Army sergeant presented to the emergency room in Bagram, Afghanistan, with penetrating neck trauma including mandible fracture, extensive soft tissue wound burns, and soft tissue loss caused by fragments from an AK-47 assault rifle bullet. After the patient's wounds were debrided at a Role 1 hospital and packed with gauze, he was aeromedically evacuated directly to Bagram. He was alert and oriented, and his initial vital signs were stable. However, he had bright red blood pouring from his mouth and neck with intermittent vomiting of bright red blood. Physical exam showed bleeding from the facial artery and veins in the right neck. The patient had no hoarseness and maintained a stable airway, and no obvious hematoma was present. Trauma resuscitation was begun in the emergency room.

Preoperative Workup/Radiology

None. Because this patient with zone B penetrating neck trauma was symptomatic with active bleeding from his neck, he was taken immediately to the operating room (OR) to secure his airway and control the bleeding.

Operative Plan/Timing of Surgery

Given the clear evidence of acute hemorrhage from his face and neck, the patient was immediately taken to the OR. Trauma patients with symptomatic penetrating neck trauma need urgent neck exploration before any imaging procedures are ordered. Standard ATLS protocol is followed with a secondary survey performed appropriately. If these symptomatic patients are otherwise stable, then consideration should be given to obtaining appropriate imaging studies (such as CT angiography) en route to the OR.

Operation

Rapid sequence intubation was performed for airway management followed by tracheotomy. Hemorrhage control by way of clamping the facial artery and vein was performed prior to laryngoscopy and fracture repair (Figure 17-1b). A right neck exploration was rapidly performed, and the carotid sheath was noted to be completely normal without bleeding or hematoma. A direct laryngoscopy was performed and no acute bleeding was seen. Open reduction and internal fixation of the mandible fracture was performed through the neck wound, and a small Penrose drain was placed and secured (Figure 17-1c). The facial wound was closed and the patient was transferred to the intensive care unit (Figure 17-1d).

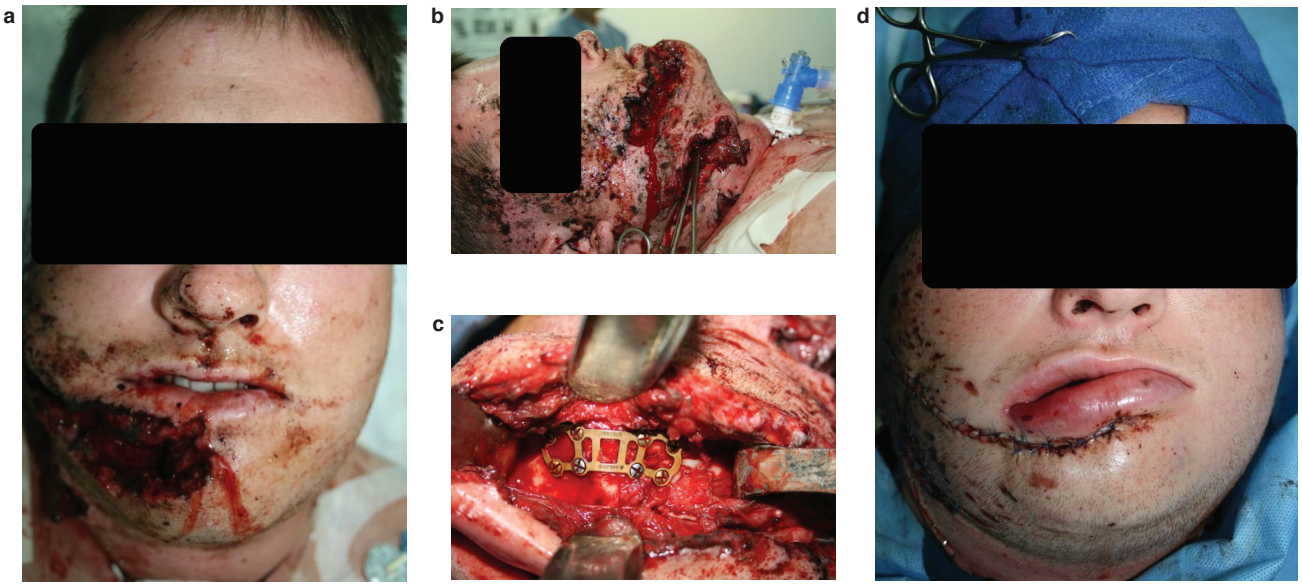

Figure 17-1. A soldier presenting for immediate repair of facial wound. (**a**) Soft tissue wound with exposed fracture; (**b**) lateral view; (**c**) open reduction and internal fixation of mandible; and (**d**) closure.

Complications

None.

Lessons Learned

The Army sergeant was observed in the Role 3 hospital for 1 day prior to transfer to Landstuhl Regional Medical Center. The patient exemplifies the criteria for immediate soft tissue repair listed previously. Because the patient presented with a soft tissue wound with exposed mandible and a repairable fracture pattern, and definitive repair would not delay his evacuation, surgery was performed to repair the fracture and close the facial wound. No further surgery was needed at Landstuhl.

The head and neck surgeon must be prepared to treat acutely symptomatic penetrating neck trauma and control bleeding. The unique skill set of a head and neck surgeon, including endoscopy skills, are necessary to rule out injury to occult vessels and manage the airway. When in doubt, an endotracheal intubation should be converted to a formal tracheotomy, and the patient should be stabilized within the Role 3 hospital with hemorrhage control and possibly definitive repair. High velocity gunshot wounds can cause extensive tissue loss, which may necessitate further debridement. In this case, the patient had been debrided twice before and the facial and neck wounds were stabilized in theater. More extensive tissue loss and severe craniofacial fractures might necessitate airway and hemorrhage management.

Case Study 17-2

Presentation

A 34-year-old Afghan male presented to the emergency room in Bagram, Afghanistan, with facial wounds from a mortar attack. The patient presented with right cheek and nasal skin loss comprising half of the right cheek, significant ocular injury, and loss of skin over five subunits of the nose. Because the injury was acute and the patient's presentation at Bagram Airfield was his first encounter with care, debridement was performed in the OR. The patient underwent CT scan evaluation of the head and neck prior to operative management. No craniofacial bony injuries were evident other than nasal bone fractures. The airway was managed via endotracheal intubation in the OR. The wound was debrided including gentle scrubbing of the facial skin with Hibiclens (Mölnlycke Health Care US, Norcross, GA) solution.

Preoperative Workup/Radiology

CT scan was performed, showing fracture of the nasal bones. Injury to the anterior chamber of the globe was evident, and a small intraocular fragment was identified.

Operative Plan/Timing of Surgery

The evident right intraocular injury was addressed initially by ophthalmology. Given the stability of the patient's airway, with no evidence of hemorrhage, the ocular injury was the priority on secondary survey. The patient also consented to facial wound debridement, paramedian forehead flap (PMFF), and cheek debridement.

Operation

The fragment was removed in the OR. Extensive debridement of the facial wounds using a saline pulse irrigator was then performed. Because the skin injury to the right cheek extended to the dermal layer only, skin closure was unnecessary. However, the extensive injury to the upper third, middle vault, and right lower alar subunit necessitated removal of skin subunits involving over 50% of the injury and closure with a PMFF (Figure 17-2b). Closure of the forehead was achieved with this interpolated flap set into the upper and middle third of the nose. The right alar region was closed primarily (Figure 17-2c). The patient was admitted for 3 days for observation and then discharged on oral clindamycin.

The patient returned for a wound check and was readmitted at 1 month for second-stage PMFF takedown (Figure 17-3c). He had very good follow-up and returned again at 3 months postinjury with good results (Figure 17-3d). During this visit he was evaluated by the ophthalmologist for right ocular injury and pseudoptosis, and the reconstructive operation to his right periocular region was deferred.

Complications

None.

Lessons Learned

Given the stability of the patient and evidence that there was no injury to the supratrochlear vessels on the left side of the forehead, a left supratrochlear-based PMFF was designed and used to correct the soft tissue deficiency evident in the upper and middle third

Figure 17-2. An Afghan soldier presenting with zone B injury to nose and right cheek. (**a**) Skin and soft tissue loss to right nose and cheek complex; (**b**) paramedian forehead flap (PMFF) plan based on left supratrochlear vessels; (**c**) PMFF inset, cheek wound debrided; (**d**) second-stage PMFF with pedicle division at 1 month; (**e**) 3-month postoperative result.

Figure 17-3. An Afghan soldier presenting after gunshot wound to the face with zone A, B, and C injuries. (**a**) Skin, soft tissue, and bony discontinuity secondary to large cavitation; (**b**) computed tomography scan showing over 2.5 cm of bony discontinuity; (**c**) after open reduction and internal fixation of the mandible and midface, a Gillies fan flap from the right upper quadrant is elevated for closure; (**d**) primary closure at first stage; and (**e**) demarcation of the wound at 3 weeks.

f

g

Figure 17-3 (continued). (**f**) Pectoralis myocutaneous flap inset; and (**g**) surgical result at 3 months.

of the nose. The PMFF and cheek debridement were performed following the ocular surgery in order to efficiently use valuable OR time and maximize patient compliance. Given the extensive facial injury and need for a flap take-down, patient education and subsequent compliance allowed for insetting the PMFF and long-term follow-up. Patient education and compliance to return to the Role 3 hospital are necessary to achieve optimal surgical results.

Case Study 17-3

Presentation

A 27-year-old Afghan male presented to the emergency room in Bagram, Afghanistan, with facial wounds from a gunshot wound to the face. The patient presented with panfacial injury to bilateral ocular and periorbital regions, with nasal, cheek, and lower face perioral loss of skin (Figure 17-3a). No other injuries were evident based on primary survey. Given the patient's extensive facial injury, he was taken to the operating for initial emergent tracheotomy. Because the injury was acute and the patient's presentation at Bagram was his first encounter with medical care, airway management was of primary concern. The patient underwent CT scan evaluation of the head and neck after tracheotomy.

Preoperative Workup/Radiology

A CT scan was performed showing a 2.6-cm bony discontinuity associated with the symphyses and parasymphyseal region of the left mandible. There were associated right Le Fort I and II fractures and a left Le Fort I fracture. Fractures of the nasomaxillary and zygomaticomaxillary buttresses were evident. Bilateral injury to the globes was evident, with hyphema formation and open injury to the both globes from intraocular fragments. Extensive upper and lower eyelid lacerations were evident.

Operative Plan/Timing of Surgery

After his airway was secured with a tracheostomy, the patient was taken back to the OR, where the ophthalmologist could adequately examine the globe. It was deemed that both globes were not salvageable and enucleation was necessary. After enucleation, the extent of maxillary and mandibular bony loss was evaluated and a step-wise approach for wound closure was formulated. Primary closure of the eyelids, midface, and lower face would allow for wound closure, but bony continuity had to be established first. Removal of remaining teeth 8, 9, and 10 was planned. The fractured teeth were evaluated by the dental service and addressed. Because the patient would be undergoing ocular surgery for enucleation, he also consented to facial wound debridement, ORIF of the bilateral Le Fort fractures, ORIF of the mandible, and local flap rotation for wound coverage of the lower face.

Operation

Enucleation of bilateral globes was performed in the OR. Removal of the facial fragments was performed, with conservative facial skin debridement. All bleeding

tissue was preserved. Attention was then given to closing the upper and lower eyelid skin by first repairing tarsal injuries, then closing the eyelid skin, followed by bilateral tarsorrhaphies. After these procedures were performed, the mandibular defect was addressed. Intermaxillary fixation was performed. Fragmentary bone that formerly comprised the symphyseal and parasymphyseal regions was plated using a 3.0-mm reconstruction bar with reconstruction screws along the inferior border of the mandible. A 2.0-mm tension titanium plate was also placed along the parasymphyseal region. Next, the Le Fort I and II fractures were repaired, leaving a right-sided maxillary defect. Enough nasomaxillary and zygomaticomaxillary buttresses remained that the midface was adequately reduced. There was no significant maxillary soft tissue defect. Nasal lacerations were closed with the remaining alar base soft tissue. Finally, a right-sided facial skin deficit remained. The need for local flap coverage became evident at this point, so a Gillies fan flap was mobilized (Figure 17-3c), and right cheek closure was achieved with the Gillies fan flap inset (Figure 17-3d).

The patient was sent to recovery, admitted on broad spectrum intravenous antibiotics, and monitored for 3 weeks with anticipation that the wound would possibly dehisce. After 2 weeks, dehiscence was evident and wet-to-dry dressing changes were performed three times per day. At 3 weeks, the wound appeared clean, and had been demarcated enough that the extent of viable remaining tissue in the symphyseal mandible was visible (Figure 17-3e). Wound cultures taken at this point did not reveal uniformity of a particular organism but showed some polymicrobial growth, likely from oral dehiscence. Bony continuity was established at this point, and the patient consented to a pectoralis myocutaneous flap to provide viable transfer of well-perfused tissue into the region.

Given the extensive devascularization associated with gunshot wounds, regional flap coverage is sometimes necessary. Although free tissue transfer could be considered in this case, lack of recipient vessels due to injury to the facial artery and vein, together with good bony continuity at 3 weeks postoperation, made a free flap unnecessary. A pectoralis myocutaneous flap was deemed most appropriate in this setting. The flap was elevated and sutured in place to the remaining dehiscent lower mandibular region. The right cheek skin where the Gillies fan flap was inset remained viable (Figure 17-3f).

The patient was readmitted and continued on broad spectrum antibiotics. He remained in the hospital for lack of medical services available in his local village. The patient was discharged at 5 weeks with a family member and returned for postoperative follow-up. He was reevaluated at 3 months, demonstrating good viability of the pectoralis myocutaneous flap, Gillies fan flap, and facial skin closures. He presented with cicatricial ectropion of the right orbit. The ophthalmologist discussed ocular implants with the patient.

Complications

None.

Lessons Learned

An urgent tracheostomy was required to stabilize the patient's impending airway status. His secondary survey was revealed that his extensive ocular injury necessitated bilateral globe enucleation, which is best performed with the ophthalmologist and otolaryngologist present. Ocular closure with tarsal repair and tarsorrhaphy is necessary for globe protection. ORIF of the mandible fracture to establish continuity is necessary to establish the base after intermaxillary fixation. Le Fort fracture repair can follow. Maxillary defects that do not involve the palate and preserve the buttresses can be left alone. Closure of the face initially by tension-free complex repair followed by local flaps is warranted in gunshot wound injuries. It is expected that extensive demarcation of the wound will take place in the region that is least vascularized. Given the loss of the facial vessels, free tissue transfer was not viable. Instead, regional tissue transfer utilizing a pectoralis myocutaneous flap, a workhorse for facial reconstruction, can be considered in the presence of a microbial neutral environment. Daily wound care is necessary prior to attempting a regional flap, and the flap must be inset in a delayed fashion. Long-term wound surveillance is necessary because cicatricial contraction of the face is likely to occur with time. As previously discussed, patient education and compliance to return to the Role 3 hospital is necessary to achieve optimal surgical results.

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