

Chapter 14

INDICATIONS FOR FACIAL AND NECK TRAUMA SURGERY

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Thus, the person intending to practice this kind of surgery must serve in the army, and accompany it on expeditions abroad; for in this way he would become experienced in this practice.¹
— Hippocrates

INTRODUCTION

As long as humans have battled against nature and each other, there have been facial and neck injuries. Because the face and neck are often exposed, these areas of the body require specialized treatment when injured. This chapter will review the history of

the treatment of facial and neck injuries, including improvements made in patient medical evacuation from theater, and describe some of the indications and limitations on in-theater repair of facial and neck injuries.

HISTORY OF MAXILLOFACIAL TRAUMA SURGICAL REPAIR

Ancient Through Mediaeval Periods

The treatment of facial trauma injuries can be dated to around 5,000 BCE, when the Sumerian physician Hammurabi described payment for physicians who set broken bones.² Techniques of local pedicle flap repair of cheek defects and forehead wounds were performed in ancient India around 1,500 BCE, as described by Graham.³ In the Edwin Smith papyrus, circa 1,600 BCE, Egyptian surgeons described replacing a dislocated mandible by “putting thumbs upon the rami of the mandible and fingers under the chin and cause them to fall back so that they rest in their places.”⁴ The pa-

pyrus also told of simple mandible fractures treated with bandages covered in honey and egg whites and facial lacerations treated by placing fresh meat on the wound the first day—perhaps distributing procoagulant factors throughout the wound.² Comminuted mandible fractures were managed differently: “Thou should say concerning him: One having a fracture in his mandible, over which a wound has been inflicted [and] he has a fever from it. An ailment not to be treated”⁴ (Figure 14-1).

Hippocrates, born in 460 BCE, provides the first description of techniques for repairing mandible fractures designed to maintain teeth integrity. He utilized strips of leather that were glued to the facial skin so that the teeth “should be connected together, not only two but more of them, with a gold thread if possible, but otherwise with a linen thread, until the bone be consolidated.”² Guglielmo Salicetti, in his *Praxeos Totius Medicinae*, describes reestablishing occlusion: “Tie the teeth of the uninjured jaw to the teeth of the injured jaw in this way.”² Ambrose Paré, a French military surgeon who published the *Cinq Livres de Chirurgie* in 1572, describes sewing skin together with plaster casts, rather than the traditional technique of cauterization, which often left terrible facial wounds.⁵

The 18th and 19th Centuries

As technology progressed past the Middle Ages, so did the management of facial trauma. Military surgeons continued to describe various techniques for repairs. In 1779, Chopart and Desault described a novel fracture reduction technique, utilizing an iron splint secured to the chin and drawing the teeth together,⁶ similar to Hartig’s appliance described in 1840.² In 1823 von Graefe described a technique of external maxillary fixation using a metal headband with extension to the maxillary dentition.² Baudens first described circummandibular wiring in 1840, which was later introduced into the United States by Black. Kinloch

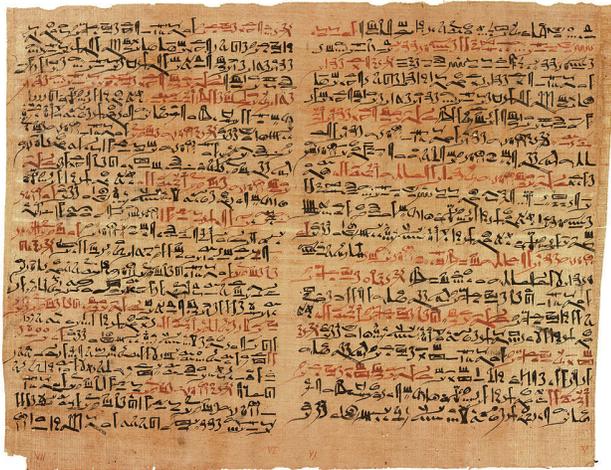


Figure 14-1. Egyptian hieroglyphs from the Edwin Smith Papyrus. “Thou should say concerning him: One having a fracture in his mandible, over which a wound has been inflicted [and] he has a fever from it. An ailment not to be treated.” Quoted in: Sykes P. The Edwin Smith papyrus [ca. 16th century BC]. *Ann Plast Surg.* 2009;62(1):3–4. Photograph reproduced from: Breasted JH. *Edwin Smith Surgical Papyrus*. Chicago, IL: University of Chicago Press, 1930.

first used transosseous wiring of the mandible bone ends in 1858 using silver wire.² Guerin first noted in 1866 that fractures of the orbit often involved the pterygoid plates.⁷

The definitive treatment of facial wounds in the 19th century was sometimes one of benign neglect. The *Medical and Surgical History of the British Army in the Crimea, Volume II* (1858), describes the reasoning for this strategy: "Wounds of the face . . . are not generally of so serious a nature as their first appearance might lead the uninitiated to expect. The reason of this . . . seems obviously to be the very free supply of blood which this part receives. This leads us to not remove bony fragments unless the comminution be great, or the fragment completely separated from the soft parts. Even partially detached teeth will often be found not to have lost their vitality and, if carefully readjusted, will become useful."⁸ These comments would likely be readily accepted by many facial trauma surgeons today. Sir Harold Gillies advocated for every patient with maxillofacial trauma to be placed prone, to prevent the soft tissue from falling into the airway.²

Thomas Gunning deserves special recognition. He developed a mandible splint using vulcanized rubber that enclosed the mandible teeth and obtained maxillary teeth impressions. The splint was then secured using thread or wires, with a cut-away portion in the front to allow passage of food. Gunning became well-known in America for his treatment of facial fractures, particularly jaw fractures. He was consulted when William H Seward, the secretary of state to Abraham Lincoln, sustained a mandible fracture from a carriage accident. Although Seward sustained a wound infection secondary to contemporary treatment techniques, Gunning was able to help him regain normal occlusion. Gunning himself sustained a mandible fracture after falling off his horse. He reduced the fracture himself, then used interdental suture and his splint to restore occlusion, and saw patients in his clinic the next day.²

The 20th Century

In the early 20th century the understanding of facial trauma surged forward. In 1901 the work of Rene Le Fort was published in France (translated into English in 1941), describing for the first time the most common midface fracture patterns.⁹ These descriptions are still used today by clinicians to describe the types of fracture sustained by facial trauma patients in the middle third of the facial skeleton. The development of radiographs and improved techniques for skin grafting and flap reconstruction enabled surgeons to increase the accuracy of their treatment. The treatment of facial

trauma was also advanced when Dr Ivan Magill developed endotracheal anesthesia in the early part of the century, allowing surgeons to work without waiting for ether to be provided.

The first military facial trauma units were developed before World War I. During the battle of Somme, Gillies created the first military unit dedicated to maxillofacial injuries, which treated over 2,000 injuries beginning on the first day of the battle.¹⁰ During the war, the work of Gillies, Fry, and Fraser in England and Blair, Ivy, and Smith from the United States formed the basis of many of the techniques used to repair facial trauma injuries.²

However, facial and neck injuries were still treated with benign neglect; surgeons would allow the wounds to heal with secondary intention, followed by scar revision and reconstruction weeks to months later.¹⁰ This often caused significant deformity from contraction and scarring. The few advancements made during World War I were often lost as surgeons returned to their home countries and resumed private practice. There were no significant conferences or collaboration efforts to continue improving upon the lessons learned in the war. Although the American Association of Oral Surgeons, the American Academy of Ophthalmology and Otolaryngology, and the American Society of Plastic and Reconstructive Surgery were founded in this period,¹⁰ these organizations initially did not focus on development of trauma management schemes nor push for cooperation and research in this area.

Significant advances in facial and neck trauma surgery occurred during World War II. The development of aircraft evacuation, use of antibiotics, improvements in anesthesia and transfusions, and advances in external fixation devices allowed improved outcomes in facial trauma patients. For example the biphasic external fixation device, also known as the Joe Hall Morris device, was developed during this period to aid in external fixation of complicated mandible fractures.¹¹

A major change occurred when British plastic surgeon Patrick Clarkson began treating facial trauma patients differently. The prevailing paradigm Clarkson deviated from was treatment with secondary intention healing with delayed reconstruction. Many surgeons believed healing with a deformity was preferable to possibly causing facial skin loss. During the battle of Cassino in Italy in 1944, Clarkson and his team of dentists, ophthalmologists, neurosurgeons, and plastic surgeons began to treat patients with early wound closure. This resulted in evacuation of only 20% of wounded soldiers back to Britain.¹⁰

As Clarkson and his colleagues continued this new treatment strategy, they noted improvements in patient outcomes. Patients treated with early closure

had not only faster healing but also faster union of underlying fractures. Since internal fixation had not yet been developed, this allowed for earlier bone grafting.¹⁰ Most fractures were definitively repaired with wiring and cast metal splints. The infection rate was 3%, and 95% of patients with isolated soft tissue injury returned to duty within 11 days. The unit's sequestration rate dropped from 70% to 10% compared to prior treatments in North Africa earlier in the war.¹⁰ Unfortunately, many of the advancements made during World War II were lost following the war for the same reason as after World War I.

The next advancement in treating head and neck facial trauma came in the 1950s with the development of advanced internal fixation techniques. In 1950 Robert Danis in Belgium described internal fixation in *Théorie et Pratique de l'Osteosynthèse*.¹² His technique allowed bones to heal without callous formation, which he termed "per primam," or primary healing. The first successful results of open reduction and internal fixation (ORIF) were described by Maurice Muller in Switzerland in 1951. Muller and colleagues developed the Arbeitsgemeinschaft für Osteosynthesefragen (AO) in 1958 and began collecting data on outcomes and improving internal fixation techniques.¹² The first AO cranio-maxillofacial trauma course was conducted by Joachim Prein in Basel, Swit-

zerland, in 1974.¹² ORIF became the primary surgical management technique for complex facial fractures over the next few decades.

The Vietnam conflict provided another opportunity for developments in the treatment of wartime facial and neck injuries. Since most of the lessons learned in World War II were lost, much of the treatment of facial fractures was based on the individual surgeon's experience, and patients were evacuated to the United States for definitive treatment. Again, wartime experience was not adequately reported, and data describing the techniques and timing of facial and neck trauma surgical repairs from Vietnam is lacking in the literature.¹³

During the remainder of the 20th century, research and development of novel techniques for ORIF and soft tissue repair continued, led by the developments of Muller and others. Many companies began developing titanium plates, absorbable plates, specialized sutures, and splints for use both in traumatic injuries and for repairing surgical defects. Surgeons around the world described unique techniques for repairing bony and soft tissue injuries. The principles of AO continued to guide many of the surgical techniques for facial fracture treatment. By the beginning of the 21st century, the strategy for treating facial trauma relied on addressing immediate life-threatening injuries first, then reducing and plating fractures with adequate soft-tissue coverage.¹⁴

INDICATIONS FOR SURGERY

The indications and timing of surgical repair of facial and neck trauma has undergone many changes over the past few decades. This section describes general topics related to timing of surgical repair in theater. For more detailed indications for surgical airways and specific injuries, see chapters 12, Airway Management; 17, Acute Soft-Tissue Injuries and Repair; 27, Complex Head and Neck Reconstruction in Theater; and 28, Penetrating and Blunt Neck Trauma.

Mechanism of Injury

In the Vietnam conflict, mechanism of injury was most commonly fragmentation wounds (62%), followed by bullets (23%), and blasts (3%).¹⁴ In the conflicts in Iraq and Afghanistan injuries were more commonly caused by blasts (58%–74%).^{14,15} Many more casualties have suffered polytrauma in these conflicts as well: only 5% of Vietnam wounded had more than two areas of the body injured compared to 69% of those transported by a critical care air transport team (CCATT).¹⁴ The difference in injury patterns may be explained by other factors such as urban versus jungle tactics and the use of improvised explosive devices versus fragmentation grenades.^{16,17}

Casualty Evacuation From Theater

A unique aspect of the recent conflicts in Iraq and Afghanistan is the rapid mobility afforded to wounded American and allied soldiers. Moving from Role 1 (combat medic and buddy care) to Role 4 (definitive care out of theater) has improved dramatically (Figure 14-2). Prior to the advances made during these conflicts, many injured service members would wait weeks or months to return to an advanced level of care in Germany or the United States. The average time to return to the United States for the injured in Vietnam was 45 days, but in the Iraq and Afghanistan conflicts that time has been reduced to an average of 4 days.¹⁸ This rapid evacuation has reduced the need for definitive treatment of complex traumatic wounds while in theater.

CCATTs and acute lung rescue teams (ALRTs) were created to transport severely injured patients to higher roles of care.^{14,15,19,20} CCATT missions to evacuate wounded personnel from Afghanistan began in October 2001 and from Iraq in 2003. Composed of a critical care-trained physician, critical care nurse, and a respiratory therapist, the teams can travel on aircraft of opportunity, usually a C-141 Starlifter or

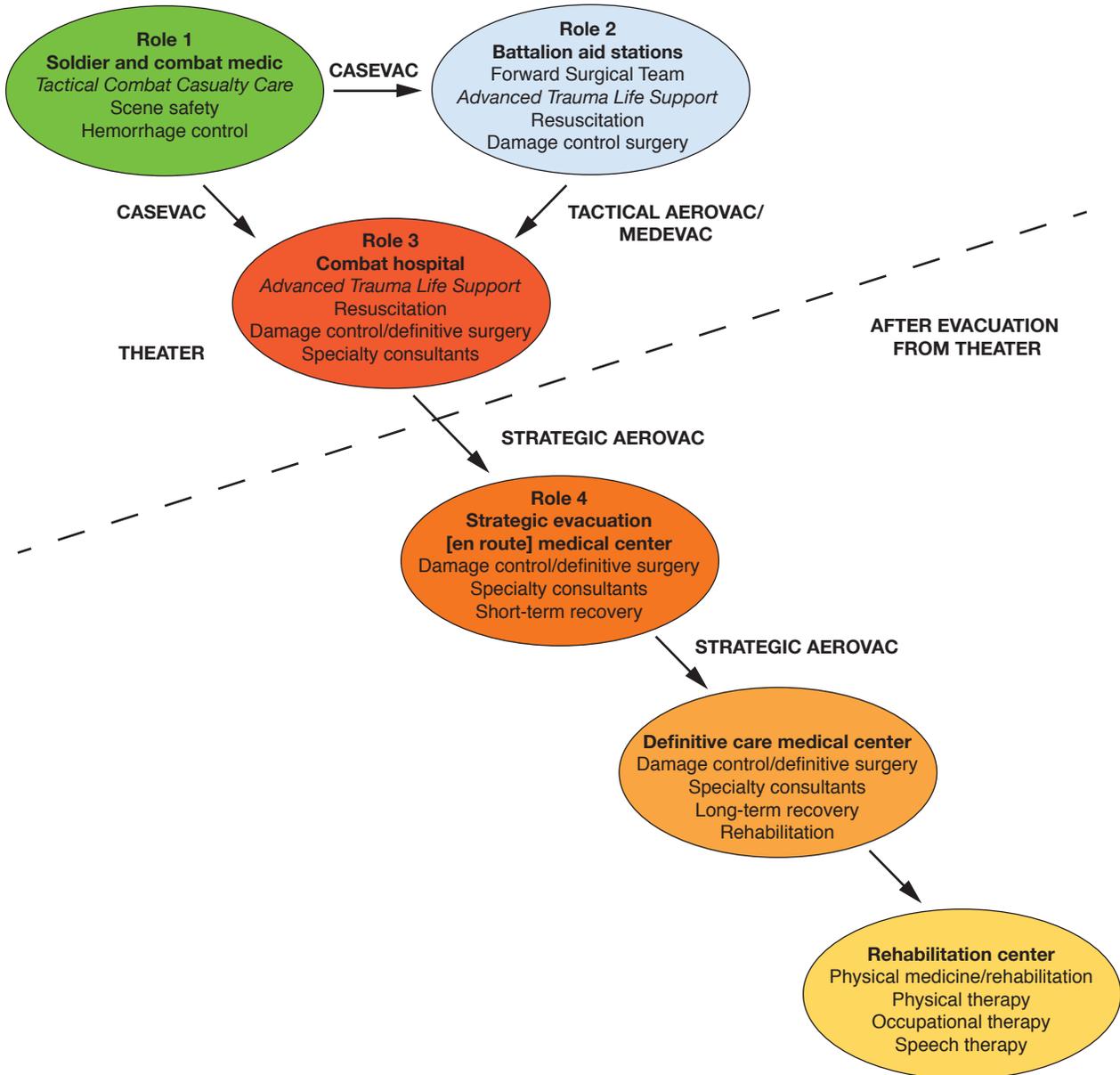


Figure 14-2. Military roles of care. CASEVAC (casualty evacuation) is movement from battlefield to military medical facility using nondedicated vehicle and personnel. MEDEVAC (medical evacuation) is transfer by dedicated medical vehicles and personnel to or between medical facilities. AEROVAC (aeromedical evacuation) uses fixed-wing aircraft to move patients between medical facilities. Tactical evacuation is movement within the theater, and strategic evacuation is between theaters. Data source: Fang R, Allan PF, Womble SG, et al. Closing the “care in the air” capability gap for severe lung injury: the Landstuhl Acute Lung Rescue Team and extracorporeal lung support. *J Trauma*. 2011;71(1 Suppl):S91–S97.

C-17 Globemaster III.¹⁴ Unlike in many previous long-range medical evacuations using the now-retired C-9, these teams do not need specialized equipment integrated into the aircraft itself, but bring all necessary equipment and supplies with them. Data on CCATT missions is available in the US Transportation Command Regulating and Command and Control Evacuation System (TRAC²ES). From 2001 to 2006,

there were 2,439 patients transported from the theater to a higher role of care, mostly to Landstuhl Regional Medical Center (LRMC) in Germany (Table 14-1). The average flight time was 6.3 ± 1.8 hours, and almost 70% of those transported had polytrauma, with more than two areas of the body injured.¹⁴ The most common types of injuries were soft tissue, orthopedic, and thoracic (Table 14-2).

TABLE 14-1

CASUALTIES EVACUATED FROM THEATER TO LRMIC BY CCATT, OCTOBER 2001 TO MAY 2006*

Category	N (%)
Military	1,749 (88%)
Army	1,263 (63%)
Marines	348 (18%)
Air Force	48 (2%)
Navy	46 (2%)
NATO	27 (2%)
Other Nation Military	16 (1%)
US Civilian	183 (9.4%)
Foreign National	43 (2%)

*N = 1,995.

CCATT: critical care air transport team

LRMC: Landstuhl Regional Medical Center

NATO: North Atlantic Treaty Organization

Data source: Bridges E, Evers K. Wartime critical care air transport. *Mil Med.* 2009;174(4):370-375.

Most of those transported by CCATT had battle injuries (64%), and most required mechanical ventilation during transport (63%).¹⁴ During Vietnam, by contrast, almost no patients were transported on ventilators. CCATTs transport patients who have been “stabilized,” that is, one who has a secured airway, accessible hemorrhage controlled, and extremity fractures immobilized.¹⁵ Physiologic stability is not implied, thus these patients may require continued hemodynamic and cardiopulmonary resuscitation en-route.

Like the CCATT, the ALRT has provided a unique capability to transport critically injured patients from the theater to higher roles of care. Unlike the “stabilized” patient transported by CCATT, the ALRT moves patients with unstable cardio-pulmonary status.²⁰ These patients have deteriorating pulmonary status, and conventional ventilation techniques are inadequate to treat them.¹⁵ The ALRT consists of two critical care-trained physicians and nurses and two respiratory technicians. These personnel are able to provide advanced cardiopulmonary support, including extracorporeal membranous oxygenation (ECMO) during transport from the theater to LRMIC.¹⁵ The efforts of the CCATT and ALRT personnel have made inter-theater transport of patients much easier, which has reduced the burden on staff and supplies within the theater and has saved many lives.

Timing of Facial Fracture Repair

Due to the rapid evacuation of allied soldiers from the theater for treatment, early in the conflict only local or host-nation personnel, who could not be evacuated,

TABLE 14-2

DISTRIBUTION OF CASUALTIES EVACUATED BY CCATT, OCTOBER 2001 TO MAY 2006*

Injury Type	Total (%)
Soft tissue trauma	948 (64%)
Orthopedic trauma	636 (43%)
Upper extremity fracture	170 (11%)
Lower extremity / pelvic fracture	323 (22%)
Fracture upper / lower extremity	131 (9%)
Pulmonary / thoracic	523 (35%)
Skull fracture	396 (27%)
Neurologic	475 (32%)
Vascular	361 (24%)
Gastrointestinal / abdominal	328 (22%)
Burns	254 (17%)
Ocular	208 (14%)
Amputation	202 (14%)
Vertebral fracture	134 (9%)
Genitourinary / renal	114 (8%)
Cardiac	19 (1%)

*N = 1,491

CCATT: critical care air transport team

Data source: Bridges E, Evers K. Wartime critical care air transport. *Mil Med.* 2009;174(4):370-375.

were being treated definitively in theater. Prior to May 2005, most allied military personnel with facial fractures were transported to LRMIC for definitive treatment.²¹ Concerns about *Acinetobacter baumannii* infection and delayed evacuation for polytrauma injuries precluded definitive in-theater treatment of facial fractures. The rate of *Acinetobacter*-related bloodstream infections was high at the beginning of the conflict, and maintaining sterility in combat hospitals was difficult, causing reluctance to place ORIF hardware in allied patients.²¹⁻²³ However, it was noted that the local and insurgent patients who underwent ORIF of facial fractures did not have an increased rate of wound infections or need for revisions, so in May 2005 allied personnel meeting strict guidelines also began undergoing ORIF of facial fractures (Table 14-3).²¹

Following these guidelines, definitive in-theater treatment of facial fractures has become the standard approach for injured allied soldiers. Coordination with CCATT missions allowed surgeons to know when patients would be evacuated to LRMIC, so they could determine the timing of facial fracture ORIF and know if it would delay CCATT evacuation. The initial study on in-theater facial fracture ORIF by Lopez and Arnholt evaluated the 16 American patients who were available for follow-up after their ORIF. None of the patients developed an *Acinetobacter* infection, and only 1 of the 16 required later plate removal and revision.²¹

TABLE 14-3
GUIDELINES FOR IN-THEATER TREATMENT OF ALLIED PERSONNEL WITH FACIAL FRACTURES

Criteria	Description
1	The fracture site was exposed either through a soft tissue wound or a surgical approach (eg, a frontal sinus fracture exposed by a bicoronal flap during a craniotomy).
2	Definitive treatment of the fracture would not delay evacuation of the patient from the theater.
3	Treatment of the facial fracture would allow the patient to remain in theater.

Data source: Lopez MA, Arnholt JL. Safety of definitive in-theater repair of facial fractures. *Arch Facial Plast Surg*. 2007;9(6):400-405.

In-theater management of facial fractures has several advantages. It has been shown that delaying fracture fixation can lead to increased technical difficulties and infectious complications.^{24,25} Soft tissue contracture around an untreated fracture and bony fibrosis can make it more difficult to completely reduce

the fracture. Nerve injuries and malocclusion can occur with mandible fractures that have delayed treatment.²⁴ Primary treatment and closure of soft tissue injuries over an ORIF also reduces the need for further facial surgery in patients who are evacuated to higher roles of care (Figure 14-3).²¹ Also, some patients treated in theater are able to return to their units, reducing critical personnel shortages (Figure 14-4).

Timing of Neck Exploration

Penetrating neck trauma in World War I resulted in a mortality rate of about 16%, possibly because nonsurgical management prevailed. The mortality rate was reduced to 7% during World War II, due to mandatory neck explorations.^{17,26,27} In Vietnam, surgical management of penetrating neck trauma reduced the mortality rate to between 4% and 7%. Brennan et al reported a 3.7% mortality rate during a 4-year period of the Iraq and Afghanistan conflicts.¹⁶ This is comparable to a perioperative mortality of about 3% for civilian patients undergoing neck exploration for low velocity penetrating neck trauma.²⁸ High velocity neck wounds are common in wartime injuries,^{17,29-31} as are injuries to vascular, nervous, and laryngotracheal structures.^{16,30}



Figure 14-3. A US soldier who sustained a right mandible ramus fracture, facial soft tissue avulsion, and right ear avulsion (a). At 8 months postoperative repair in theater (b), the patient has scarring, but had required no further maxillofacial treatment.



Figure 14-4. A US soldier with a depressed left zygomatic arch fracture, who was treated in theater and returned to duty. The patient never left the theater for treatment.

Controversy still exists about the need for mandatory neck exploration for patients in theater. Much of the US literature focuses on low velocity neck wounds, compared to many combat injuries caused by high velocity (over 610 m/s) projectiles.¹⁷ The availability of medical evacuation resources factors significantly into decision-making about the timing and need for surgical exploration. Life-threatening injuries can often be controlled at Role 2 or 3 facilities, but if a surgical exploration would delay a stabilized patient's evacuation by CCATT, it is unclear if it is necessary to perform it while in theater. The difference between mandatory and selective neck exploration for high velocity penetrating neck trauma in wartime injuries treated at a Role 3 facility was defined in a study by Brennan et al in 2011.¹⁶ Symptomatic patients with high velocity penetrating neck trauma are defined as those with penetrating neck injuries and hemodynamic instability, expanding hematoma, or obvious laryngotracheal injuries. Using a selective neck exploration algorithm with workup including computed tomography angiography (CTA) and panendoscopy, if indicated (Figure 14-5), military head and neck surgeons in Iraq demonstrated an rate of positive neck exploration of 69%,¹⁶ similar to most other series using selective algorithms.³²⁻³⁶

The use of CTA has changed the management of asymptomatic penetrating neck injuries. CTA's sensitivity ranges between 90% and 100%, and its specificity is between 93% and 100%.^{36,37} Positive scans of probable injuries demonstrate hematoma, subcutaneous air adjacent to the carotid sheath or aerodigestive tract, intravenous contrast extravasation, and missile tracts in close proximity to vital structures. Fox et al

described the limitations of wartime CTA, which found 9.5% of occult arterial injuries.¹⁹ Questions remain as to how to manage these injuries when CTA is not available, such as at a Role 2 facility or if the CTA scanner is nonfunctional. In those cases, surgeon judgment should prevail, with a lower threshold for mandatory neck exploration.

Panendoscopy has also been found to be very useful in managing penetrating neck injuries. Multiple authors have identified increased morbidity and mortality when surgery is delayed longer than 12 to 24 hours after injury.³⁸⁻⁴³ Using contrasted swallow studies and direct laryngoscopy, esophagoscopy and bronchoscopy can identify these injuries to distinguish patients who need neck explorations from those who do not.⁴⁴ Using endoscopy under general anesthesia can identify 100% of cervical esophagus and hypopharyngeal injuries according to some studies.^{42,43} Often swallow studies cannot be performed in theater, but most Role 3 facilities with a head and neck surgeon have the ability to perform endoscopy under general anaesthesia.¹⁷

Another criterion for successful neck exploration is the availability of surgical specialists with experience managing complex neck wounds. Vascular surgeons, trauma surgeons, and head and neck surgeons working together is the ideal situation. Their array of arterial bypass, vessel repair, and endoscopy skills allows the most robust management.²⁸ These specialists are also uniquely capable of observing those patients who do

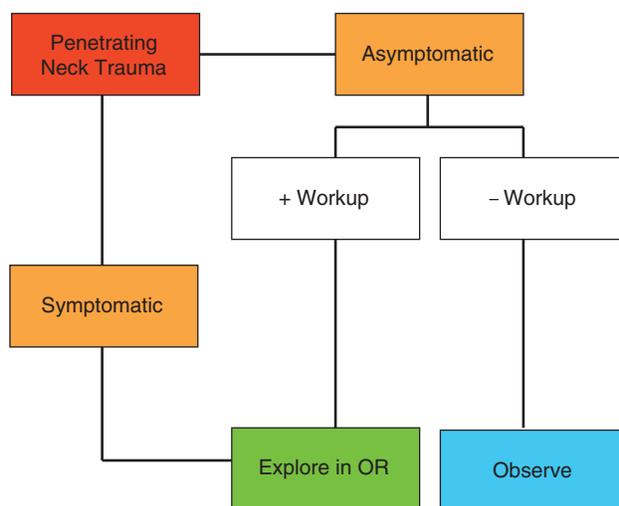


Figure 14-5. Selective neck exploration algorithm.

OR: operating room

Data source: Brennan J, Lopez M, Gibbons MD, et al. Penetrating neck trauma in Operation Iraqi Freedom. *Otolaryngol Head Neck Surg.* 2011;144(2):180-185.

not undergo neck exploration and determining if future surgery is required.^{17,19} If diagnostic testing with CTA and panendoscopy and appropriate personnel are

not available, penetrating neck injury patients should undergo mandatory neck exploration or be transferred to a facility with these capabilities.

SUMMARY

Facial and neck trauma is common in wartime. Recent conflicts have highlighted the need for rapid evaluation and treatment of facial and neck trauma in time of war, and rapid advancements in the development and application of surgical

treatment of these injuries have been made. The criteria for in-theater repair of facial fractures and management of neck trauma have evolved and continue to change as more is learned about these complex injuries.

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