Chapter 28

PENETRATING AND BLUNT NECK TRAUMA

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INTRODUCTION

This chapter is broadly divided into three sections. It begins by examining the evolution of the combat zones in Iraq and Afghanistan. This includes a review of changes in the mechanism of injury over time, a discussion of the mortality of wounds to the neck, and a comparison of lethality between gunshot wounds and explosive devices. The second section begins with lessons learned and offers several practical approaches to initial assessment and early interventions to be considered for patients with concomitant neck injuries and airway compromise or severe hemorrhage. This is followed by a review of surgical decision-making for management of penetrating neck wounds by zone and recommendations for evaluating patients with blunt neck trauma. The final section includes three case studies of neck injuries with a discussion of presentation and management.

EVOLUTION OF IN-THEATER SURGICAL MANAGEMENT

Surgical management of neck wounds in the combat theaters of Iraq and Afghanistan evolved as surgeons gained experience with blast injuries, and as logisticians made resources reliably available and brought advanced technology into combat zones. During the initial phase of Operation Iraqi Freedom (OIF), from the invasion in March 2003 through January 2004, surgical decisions were heavily influenced by resource limitations. The use of improvised explosive devices (IEDs) was infrequent in the first 10 months of the conflict, and the first surgeons in Army combat support hospitals (CSHs) in Baghdad (10th CSH), Balad (21st CSH), and Tallil (86th CSH) followed protocols they were familiar with from training and experience at civilian trauma centers.

IEDs had become commonplace by the spring of 2004, and were involved in over 20 US service member deaths per month in March, April, and May of that year.[1] Compared to trauma seen in previous US combat engagements or at US civilian trauma centers, the patterns of injury created by high energy explosive devices were more variable and the damage inflicted less predictable. Although experience with blast injuries was well described from other conflicts in the Middle East, deployed US military surgeons had limited experience with this mechanism of injury. They quickly adopted a "damage control surgery" approach for polytrauma patients with blast injuries. The goal of this approach was to stabilize the patients and transport them to a higher role of care as rapidly as possible. Anecdotally, the threshold for neck exploration by most trauma surgeons in the first 12 months of the conflict in Iraq was low.

By July 2004, advanced radiographic equipment (computed tomography [CT] scanners) and endoscopic surgical sets had become available to surgeons at both the 10th CSH in Baghdad and at the Air Force theater hospital (332nd Expeditionary Medical Group) in Logistics Support Area Anaconda near Balad (formerly Al-Bakr Air Base). CT angiography (CTA) changed the management of patients with penetrating injuries of the neck in the combat zone. CTA examination of the vasculature, with its ability to accurately detect retained projectiles and occult injuries to the great vessels of the neck, rapidly became the preferred method of evaluation. Brennan et al's review of neck explorations performed in OIF (2004–2007) revealed that US surgeons shifted toward selective neck exploration to treat patients with high velocity penetrating neck trauma (HVPNT).[2] In this review, 74% of patients who underwent neck exploration had a CTA performed preoperatively.

Use of preoperative CTA in place of standard angiography in theater reflected changes occurring in civilian trauma centers in the United States. In a 2008 article in the *Journal of Trauma*, Osborn et al published results of a 5-year retrospective study (2000–2005) evaluating the role of CTA in clinical decision-making in the management of penetrating injuries to the neck in civilian trauma centers.[3] He reported that the use of CTA eliminated the performance of negative neck explorations without increasing adjunctive studies (esophagography, angiography, and various endoscopic procedures) with no reported difference in morbidity or mortality. The practice of preoperative CTA continued throughout the remainder of OIF and Operation Enduring Freedom (OEF).

INCIDENCE, MECHANISM OF INJURY, AND MORTALITY

Incidence

The incidence of neck wounds reported in OIF and OEF varies from 2.2% to 10%.[4–6] This variance is a result of differences in the time frame studied, population inclusion criteria, ways in which wounds were grouped and counted, and the nomenclature used to describe the mechanism of injury. Reviews show that weapons, tactics, mechanisms of injury, and patterns of wounding changed as the conflicts evolved. For

example, Belmont et al noted that from 2005 to 2007, explosive mechanisms of injury were significantly more common in Iraq than in Afghanistan, but the percentage of injuries caused by explosion increased significantly in Afghanistan between 2007 (59.5%) and 2008 (73.6%).[7]

Data collection from the battlefield also matured with time, and it is essential to understand the nature of the sources used. Registries such as the Joint Theater Trauma Registry (JTTR) have been used as a data source for many statistical reviews of combat injuries. The JTTR is maintained by the Joint Trauma System of the US Army Institute of Surgical Research. The JTTR is not a medical record, a research database, or a patient tracking tool. Rather, it is a compilation of information transcribed from medical records, expert clinical inference, scoring and coding schematics, probability determination, and performance improvement data. Some data points are the result of interpretation of available clinical records.[8] Similarly, the Navy-Marine Corps Combat Trauma Registry (NMCCTR) is composed of data sets describing events that occurred from the point of injury through the medical chain of evacuation and on to long-term rehabilitative outcomes. Data were collected from Navy-Marine Corps Role 1, 2, and 3 medical treatment facilities.[9] Registries of this nature contain entries derived from clinical inference or interpretation of other information. Neither the JTTR nor the NMCCTR include uniform data collected about service members who were killed in action (KIA). These datasets have great value, but their limitations must be understood before drawing conclusions about specific subsets of the data.[10,11]

Zouris et al reviewed wound data recorded in the NMCCTR from 279 injured US marines and sailors, not including KIA, during the invasion (March 23, 2003 through April 30, 2003) and reported that 2.2% were classified as neck wounds (7 of 323 total wounds).[4] Owens et al queried the JTTR for combat injuries in US service members, wounded (not killed) from October 2001 through January 2005, and reported that 3% (207 of 6,609) were listed as neck wounds.[5] Breeze et al reviewed hospital and postmortem records, thus including service members reported as KIA, for all United Kingdom (UK) service members sustaining battle injuries to the neck between January 1, 2006 and December 31, 2010, and reported neck wounds were present in 10% (152 of 1,528).[6]

Many authors report neck wounds combined with head and face wounds. In Owens' query of the JTTR for injuries of the head and neck from October 2001 through January 2005, 30% of wounds involved one or more areas of the head and neck when all areas are included: head (8%), eyes (6%), ears (3%), face (10%), and neck (3%).[5] Wade et al reviewed data on US military casualties from the NMCCTR (injuries occurring between March 1, 2004, and September 30, 2004) and reported that 39% of casualties had head, face, and neck injuries.[12] The relative proportion of wounds to the head and neck in OIF and OEF in these reports is higher than reported in comparable data from World War II, Korea, or Vietnam (16%–21%).[13–15]

Mechanism of Injury

Blast or explosion was the most common cause of injuries to the neck in OIF and OEF. Breeze found that 79% of neck wounds in 152 UK service members sustaining battle injuries (January 1, 2006–December 31, 2010) were caused by explosions and 21% were caused by gunshot wounds.[6] Ramasamy et al reviewed an overlapping dataset of 90 British military casualties from Iraq and Afghanistan between 2003 and 2009 and found that the mechanism of injury was explosion in 66 cases (73%) and gunshot wounds in 24 cases (27%).[16]

Brennan compiled data from 112 neck explorations for penetrating neck trauma performed by six otolaryngologists deployed to Balad, Iraq, between 2004 and 2007, reporting that high velocity projectiles caused 95% of the injuries (106/112).[2] In his study, IEDs accounted for 56% of the wounds (63/112); gunshot wounds, 26% (29/112); mortars/rockets, 12% (13/112); rocket-propelled grenades/hand grenades, 1% (1/112); knives, 1% (1/112); and motor vehicle accidents, 1% (1/112). The mechanism of injury was unknown in four patients. Secondary blast injuries in this study accounted for 69% of the wounds (77/112).

Feldt et al queried the JTTR for combat injuries sustained by 7,177 US service members in Iraq and Afghanistan from 2003 through 2011 and reported that out of 37,523 total discrete facial and penetrating neck wounds, 73.3% had a mechanism of injury recorded as either penetrating (49.1%) or blast (24.2%).[17] Blunt trauma was recorded as the mechanism of injury in 25.7% of cases. However, the data set did not clearly distinguish whether injuries caused by blast were primary (from the pressure wave), secondary (from propelled debris), or tertiary (from the impact of the body being pushed into an object), and the data does not permit separation of facial and penetrating neck injuries from other types of injuries for individual patients.

These reports are consistent with the mechanism of injury found when queries are extended to include all wounds. Owens' query of the JTTR revealed that explosions caused 78% and small arms fire caused 18% of all wounds (October 2001–January 2005).[5] Belmont et al's review of data from the JTTR from 2005 through 2009 found that explosions were the mechanism of injury in 74.4% and gunshot wounds in 19.9% of cases.[18]

Mortality

Penetrating neck trauma historically has a high mortality rate. During the Civil War, Spanish American War, and World War I, when nonsurgical management was performed, 11% to 18% of combatants with neck injuries were reported to have died of their wounds.[19,20] During World War II, mandatory neck exploration was instituted and mortality fell to 7%, remaining in the 4% to 7% range during the Vietnam War.[21] Data on mortality from wounds to the neck in OIF and OEF is varied and difficult to draw conclusions from. Wade reported that 4% of 445 casualties with head, face, or neck injuries died from wounds (NMCCTR; March 1, 2004–September 30, 2004).[12] Feldt reported that facial and penetrating neck injuries were associated with a respective mortality rate of 4.1% in OIF and 2.3% in OEF, for an overall mortality rate of 3.5%.[17] In Feldt's review, the strongest risk factors for mortality included treatment at a Role 2 facility (with surgical capabilities), female gender, prehospital intubation, and blast injury. Brennan reported a mortality rate of 3.7% for patients undergoing neck exploration for high velocity penetrating neck trauma in his review (112 neck explorations in Balad, Iraq, 2004–2007). However, none of these studies included data on combatants killed before reaching the medical system.

Perhaps the most complete and best validated data on overall mortality caused by wounds to the neck comes from studies that include hospital and postmortem records for UK service members sustaining battle injuries to the neck reported by Ramasamy et al[22] and Breeze et al.[6] Ramasamy reported that neck wounds in their study population were associated with a mortality rate of 46%.[22] Breeze reported that neck wounds caused by explosions were associated with a mortality rate of 41%, compared with 78% for those caused by gunshot wounds.[6] The most common cause of death in this study was from vascular injury caused by explosive fragments (85%). Zone II was the most common subsite of the neck wounded and had the highest mortality. Breeze's study included 346 UK service personnel who were KIA or died of wounds, and the authors postulated that 16 of these deaths could potentially have been prevented had the soldiers been wearing antiballistic cervical collars.

The lethality of vascular injuries parallels the civilian trauma experience and is consistent across time. In 1963, Stone and Callahan reported that vascular injuries in the neck accounted for 50% of deaths from these wounds.[23] Thirty years later, in a multi-institutional review of penetrating neck injuries from 16 US medical centers, McConnell and Trunkey reported that the number one cause of death from penetrating neck trauma was exsanguinating hemorrhage.[19]

ANATOMICAL CONSIDERATIONS

Key Anatomic Landmarks and Major Functional Divisions of the Neck

Two muscles of the neck serve as key landmarks, and their importance must be appreciated. The *platysma muscle* separates superficial from deep structures of the neck. If a wound does not penetrate deep to the level of the platysma, it is not a penetrating neck wound. Although the transverse cervical veins lying superficial to the platysma may be large and can bleed profusely when severed, they are easily controlled with direct pressure and can be managed with simple ligature. The sternocleidomastoid muscle (SCM) divides the neck into the anterior triangle and posterior triangle. Generally speaking, the posterior triangle contains the spine, muscles, and cervical plexus, whereas the anterior triangle contains the named vasculature, cranial nerves IX through XII, airway, esophagus, and glands.

The importance of two structures that serve as key landmarks must also be appreciated. The mandibular angle separates the middle portion of the neck from the upper cervical region associated with skull base structures. The cricoid separates the middle portion of the neck from the lower cervical region associated with the great vessels of the thorax. The clinical importance of these divisions are discussed in the section on Zones of the Neck.

It is also useful to consider each of the five major functional groups of the neck separately during the secondary survey to ensure a comprehensive assessment is performed, as well as when planning surgical approaches:

1. *airway*: pharynx, larynx, trachea
2. *major vessels*: carotid arteries, innominate artery, aortic arch vessels, jugular veins, subclavian veins
3. *gastrointestinal tract*: pharynx, esophagus
4. *nerves*: cranial nerves, spinal cord, brachial plexus, peripheral nerves
5. *bones*: mandibular angles, styloid processes, cricoid, spine

An easily missed major cause of late mortality in patients with penetrating neck wounds is esophageal injury, which may be asymptomatic on presentation.

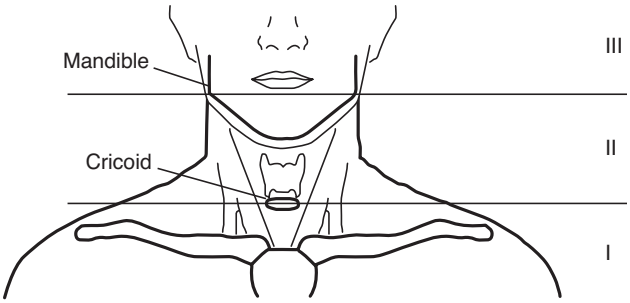

Figure 28-1. Zones of the neck.

Evaluation of the esophagus in these patients must not be overlooked. Surgical repair or drainage performed less than 24 hours after the injury can result in survival rates higher than 90%, but when surgical treatment was performed more than 24 hours after the injury, survival dropped to 65% in a review by McConnell et al.[19] Esophageal injury and laryngotracheal injury are discussed in detail in in Chapter 29, Management of Acute Laryngotracheal Trauma, and Chapter 40, Delayed Management of Laryngotracheal Trauma.

Zones of the Neck

When evaluating penetrating injuries, the neck is commonly divided into three anatomic zones for purposes of initial assessment and management planning (Figure 28-1). The utility of this division is based upon two concepts: injury patterns and surgical management approaches. As previously noted, injury patterns from high energy explosives are extremely variable, and observing an external wound in a particular zone has limited value in predicting the location of underlying injuries. However, the challenges associated with surgical exploration and hemorrhage control are distinctly different in each zone, and must be considered in surgical planning. The boundaries and major contents of each zone are reviewed below, and the impact of injuries on management planning is discussed by zone in a later section, Surgical Decision-Making for Penetrating Neck Wounds.

Zone I is the horizontal area between the clavicle/suprasternal notch and the cricoid (including the thoracic inlet). Surgical access to this zone may require thoracotomy or sternotomy; management of vascular injuries here is challenging; and mortality from injuries in this zone is high. The proximal common carotid; vertebral and subclavian arteries; subclavian, innominate, and jugular veins; proximal trachea; recurrent laryngeal nerves; esophagus; thoracic duct; lower thyroid and parathyroid glands; and thymus are located in this zone.

Zone II is the area between horizontal lines drawn at the level of the cricoid cartilage and the angle of the mandible. Surgical access to this zone is straightforward, via a standard neck exploration incision. Zone II contains the internal and external carotid arteries, jugular veins, pharynx, larynx, esophagus, recurrent laryngeal nerves, spinal cord, trachea, upper thyroid, and parathyroid glands.

Zone III lies between the angle of the mandible and the base of the skull. Surgical access to this zone often requires mandibulotomy or maneuvers to anteriorly displace the mandible, and may require craniotomy. Management of vascular injuries here is difficult, and mortality from injuries here is high. Zone III contains the extracranial carotid and vertebral arteries, the jugular veins, cranial nerves IX through XII, and the sympathetic trunk.

LESSONS LEARNED

The following lessons learned have gained wide acceptance and are considered basic tenets of the management of penetrating neck wounds.

- The ability to obtain a surgical airway is a critical skill.
- Direct pressure on or packing a wound will temporarily control hemorrhage associated with survivable penetrating neck wounds.
- Surgical exploration should be considered for zone II neck injuries that penetrate the platysma, but may be delayed while studies of the major vessels, trachea, and esophagus are obtained if the casualty is asymptomatic.
- Small penetrating wounds to the neck from an IED can be deceiving.
- Injuries that penetrate the platysma should not be probed.
- Radiographs do not rule out esophageal injury.
- Casualties with active hemorrhage, an expanding hematoma, bruit, pulse deficit, subcutaneous emphysema, hoarseness, stridor, or respiratory distress have indications for immediate operative management and require urgent consultation with a surgeon.

INITIAL ASSESSMENT AND EARLY INTERVENTIONS

Regardless of the mechanism of injury, orderly assessment of casualties following advanced trauma life support (American College of Surgeons) principles is appropriate and is discussed in Chapter 11, Primary and Secondary Trauma Assessment. Rigorous spinal precautions are important, but do not take precedence over maneuvers necessary to manage life-threatening airway or vascular injuries. Panendoscopy (esophagoscopy, laryngoscopy, and bronchoscopy) is a critically important skill for managing trauma to the airway and identifying occult esophageal injuries that may be lethal. Skilled endoscopists with the proper equipment (flexible and rigid esophagoscopes and bronchoscopes and rigid laryngoscopes) provide a wide variety of diagnostic and treatment options that make management of penetrating neck trauma safer and more effective. Swallow studies such as esophagograms have not been used widely in theater. Below is a brief review of specific considerations in the initial management of casualties with neck wounds.

Airway Management

The airway should be considered threatened in any casualty who presents with a penetrating neck wound. Casualties who appear to have a minor neck wound may have a clinically significant underlying injury. Stridor, hoarseness or dysphonia, hemoptysis, and subcutaneous air should be specifically looked for, and indicate a potentially serious injury to deeper structures.

Orotracheal intubation is the initial method of choice for securing the airway under most circumstances. Nasal intubation and fiberoptic intubation techniques are technically more difficult, require special equipment, and should be reserved for elective airway management. Use of a laryngeal mask to ventilate a casualty may serve as a bridge to buy time, but it is not a secure airway. Distorted laryngeal landmarks or a pharynx filled with blood can make endotracheal intubation difficult, and repeated blind intubation attempts risk enlarging a penetrating injury of the pharynx.

Cricothyroidotomy is the preferred method for establishing an immediate airway if rapid endotracheal intubation is not possible or is contraindicated. In casualties with large penetrating anterior neck wounds who require an urgent airway, consider extending the wound as necessary and intubating through the wound by isolating the trachea between two fingers and completing an incision into the anterior trachea.

Bleeding Management

Exsanguinating oropharyngeal hemorrhage should be controlled by obtaining an immediate surgical airway (cricothyroidotomy or tracheotomy) followed by packing the pharynx. Pharyngeal packing after an airway has been secured is most effective at controlling severe hemorrhage if the source can be identified. For this maneuver, diffuse bleeding may require a full Kerlix (Covidien, Dublin, Ireland) roll or more to tamponade. To control arterial bleeding, the amount of packing is not as important as placement, keeping in mind that the packing used must be placed to apply sufficient pressure on the bleeding vessels, and opposing pressure applied to the external neck may be required. The casualty is then taken to the operating room (OR) for definitive exploration.

Blind clamping of bleeding vessels in the neck is inadvisable. Most survivable hemorrhage from neck wounds can be controlled with directed pressure above and/or below the wound (compressing a bleeding vessel against the vertebrae), application of pressure directly over the wound, or by packing the wound with gauze. Vaginal tampons inserted into a 1- to 2-cm bleeding laceration caused by shrapnel can be effective at controlling hemorrhage, and many experienced medics carried them (Figure 28-2).

External carotid artery injuries are easily managed by suture ligation. All veins in the neck can be safely ligated to control hemorrhage. Casualties with large venous injuries should be placed in the Trendelenburg position if there is any concern about internal jugular (IJ) vein injury and possible air embolus. If both IJ veins are interrupted by the injury, an attempt to repair one is appropriate to reduce the risk of complications result-

Figure 28-2. Tampon placed in neck wound to control bleeding.

ing from elevated intracranial pressure. If bilateral IJ vein ligation is performed, careful postoperative fluid management is required, and tracheotomy placement should be considered due to subsequent severe head and neck edema.

Open neck wounds should not be probed. If violation of the platysma is uncertain, the wound edges should be gently spread without probing until platysma violation is recognized. Probing may lead to clot dislodgement, and vigorous bleeding can occur. Open wounds that do not penetrate the platysma do not cause significant problems unless there has been a concomitant blunt injury.[24] Intravenous access should be obtained on the opposite side of zone I injuries to avoid potential extravasation of fluids from a subclavian vein injury.

SURGICAL DECISION-MAKING FOR PENETRATING NECK WOUNDS

Zone I Wounds

Zone I injuries are reported to have a mortality rate as high as 12%.[25] The bony thorax and clavicle make surgical exploration of the root of the neck challenging. Stable casualties with zone I injuries should be further evaluated by CTA or arteriography, laryngoscopy, and esophagoscopy. Unstable casualties with zone I injuries require a median sternotomy or left anterior thoracotomy to control hemorrhage. Achieving hemorrhage control of penetrating vertebral artery injuries in this area can be very challenging and is associated with high morbidity and mortality rates. Surgical repair is preferred unless the patient has already developed neurological changes consistent with coma and arteriogram confirms absence of antegrade flow. The decision to explore a zone I injury should be reserved for surgeons with experience in these approaches.

Zone II Wounds

The majority of penetrating neck wounds involve zone II. Brennan found the following distribution in his study of 112 consecutive neck explorations performed in Balad, Iraq (2004–2007): zone I injuries occurred in 10%, zone II injuries in 77%, zone III injuries in 5%, combined zone I and II injuries in 5%, and combined zone II and III injuries in 3%.[2]

US military surgeons in OIF/OEF commonly managed HVPNT patients following an informal selective neck exploration protocol and achieved mortality rates equivalent to civilian trauma center mortality rates for low velocity penetrating neck wounds.[2] Brennan reported a positive exploration rate (patients with intraoperative findings necessitating surgical repair) of 69%. The negative exploration rate in his study was 31%.[2] Although management of zone II injuries continues to be debated, the safety of selective operative management of zone II injuries by experienced surgeons has been demonstrated in both community hospital and trauma center settings, with no difference in morbidity or mortality.[26–28] In a thorough review of this subject, Tisherman et al evaluated 112 articles examining mandatory exploration of all patients with penetrating neck wounds versus selective exploration based on physical examination with or without use of current imaging technologies, and summarized their conclusions as clinical practice guidelines.[29] They found strong evidence that selective operative management and mandatory exploration of penetrating injuries to zone II of the neck have equivalent diagnostic accuracy, and recommended selective exploration to minimize unnecessary surgery.

The use of CTA has also been shown to safely decrease the number of negative neck explorations. CTA or duplex ultrasound can be safely used in lieu of arteriography to rule out an arterial injury in penetrating injuries to zone II of the neck.[30–33] CTA has a sensitivity greater than 90% and a specificity ranging between 93% and 100%, and is generally accepted as the initial procedure of choice to evaluate the cervical vasculature in asymptomatic penetrating neck trauma.[3,29–31,34] Although careful serial physical examination including auscultation of the carotid artery is over 95% sensitive for detecting arterial or aerodigestive tract injuries that require repair, surgeons should have a low threshold for obtaining imaging studies when available.[29,35,36]

The decision to explore a high velocity penetrating neck wound, as described by Brennan and recommended here, is determined by the patient's symptoms at presentation, regardless of the mechanism of injury. Patients with penetrating neck injuries are triaged into symptomatic or asymptomatic groups (Figure 28-3) and managed as follows:

- *Symptomatic-unstable patients* are explored in the OR.
- *Symptomatic-stable patients* may undergo preoperative CTA if available en route to the OR to assist with surgical planning. This is especially advantageous if considering anatomic approaches to zones I and III of the neck.
- *Asymptomatic patients* are evaluated with diagnostic studies guided by the location of the wound and often dictated by availability of resources. If the diagnostic workup is positive

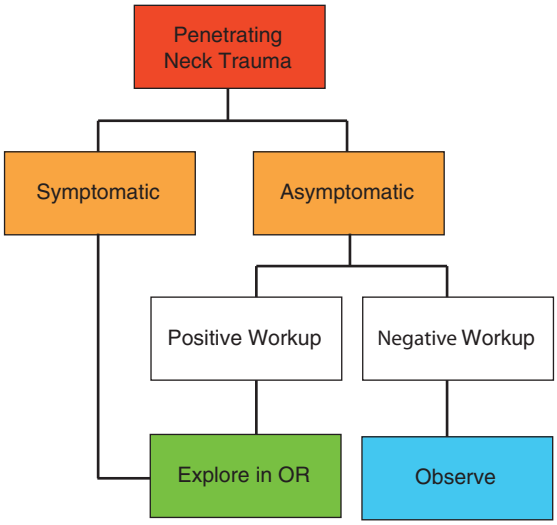

Figure 28-3. Triage flowchart for penetrating neck wounds.

or equivocal, these HVPNT patients undergo neck exploration.

- *Asymptomatic patients who have a negative diagnostic workup* can be observed. (Brennan et al did not report HVPNT patients managed by exam and observation only.)

When CTA or arteriography, laryngoscopy, and esophagoscopy are not available, asymptomatic casualties with penetrating zone II neck wounds should be surgically explored or monitored continuously until they can be transferred to a facility with advanced capabilities. A low threshold for proceeding to surgical exploration is suggested for casualties with multiple penetrating zone II neck wounds, or if the mechanism of injury is shrapnel from a high energy explosive device. Observation of casualties with penetrating zone II neck wounds from blast injuries without obtaining an alternative evaluation of the great vessels, trachea, and esophagus (observation alone) is not recommended.

Deaths from penetrating cervical injuries are frequently associated with vascular injuries, and repair of these injuries takes precedence over repair of other structures. In theater, major arterial injuries have been repaired by vascular and general surgeons. Surgical planning for repair of other injuries was adapted to ensure vascular anastomoses were protected.

A variety of surgical approaches to penetrating neck wounds have been described. Large wounds may not require a separate incision, or may be extended to obtain exposure (Case Study 28-1). When presented with small penetrating cervical wounds, rapid exposure of the great vessels is most directly obtained through a vertical incision paralleling the anterior border of the SCM (Case Study 28-2). When laryngeal or pharyngeal exposure is needed, a wide-apron incision made from the mastoid tip to the midline of the neck at the cricoid level offers greater exposure of the pharyngeal and upper airway structures.

Zone III Wounds

Zone III injuries are also associated with a high mortality rate. The skull base, styloid process, and mandible make surgical exposure in this area difficult. The mandible may need to be divided or displaced anteriorly by dividing the stylomandibular ligament. Craniotomy may be required to control a high carotid injury in this location. Stable casualties with zone III injuries should be further evaluated by CTA to exclude carotid or vertebral artery injuries. When arteriography is not available, frequent intraoral examination should be performed to observe for edema or expanding hematoma within the parapharyngeal or retropharyngeal spaces. Nerves exiting the skull base are in close proximity to the great vessels; thus, an abnormal neurologic examination in a stable casualty with a zone III injury suggests a greater likelihood of injuries to the great vessels.

Bleeding from the internal carotid artery (ICA) in zone III may be controlled by passing a No. 4 Fogarty catheter proximal to the injury and inflating the balloon to occlude the lumen,[37] or the ICA may be rapidly exposed and ligated through an incision parallel to the anterior border of the SCM. If the ICA is ligated, the distal injury may continue to bleed from collateral circulation through the circle of Willis, and require packing as the artery enters the skull base. Achieving hemorrhage control of penetrating vertebral artery injuries can be very challenging and is associated with high morbidity and mortality rates. Further discussion of surgical and non-surgical management of these injuries can be found in standard textbooks such as *Cummings Otolaryngology: Head & Neck Surgery*, 5th edition.[38] The decision to explore a zone III injury should be reserved for surgeons with experience performing these approaches. It is recommended that a neurosurgeon or orthopedic surgeon with experience managing spine and skull base trauma be consulted in the management of all casualties with these injuries.

Wound Management Considerations

Although studies have shown it is safe to close uncontaminated penetrating neck wounds primarily within 6 hours of injury, there is insufficient evidence to make a recommendation regarding primary closure

of wounds created by blasts.[39] IEDs present two significant risks for wound infection and breakdown: gross contamination with debris included in the IED (eg, grease and feces) and burns. Early removal of gross contaminants, irrigation in the OR, and prophylactic treatment with intravenous antibiotics is strongly recommended. Tissue damage from third-degree burns requires debridement and coverage with grafts or flaps.

BLUNT NECK TRAUMA

Blunt trauma to the neck in Iraq and Afghanistan was uncommon. Low numbers of blunt neck trauma in theater have been reported from motor vehicle crashes, assault, sports injuries, hanging, and clothesline trauma. The mechanism of injury, clinical considerations, and management of these injuries during combat operations generally aligned with information and recommendations from the literature on civilian blunt neck trauma.

Presenting signs and symptoms of neck injuries secondary to blunt trauma are caused by dysfunction of the affected anatomic structures. The laryngotracheal airway and cervical spine are the anatomic structures most susceptible to injury in blunt neck trauma. Anticipating an unseen airway injury and its evolution can convert a potential disaster into a manageable event and minimize long-term sequelae. Vascular injuries are potentially devastating, and fortunately very uncommon, occurring in 0.08% to 1.5% of blunt neck trauma in civilian series.[40,41]

Evaluation of patients with these injuries should follow a rapid, orderly process beginning with stabilization of the cervical spine. Securing the airway in the OR is recommended in the setting of acute airway compromise. Hemodynamic instability with signs of vascular injury, such as bruit, expanding or pulsating hematoma, hemorrhage, or loss of pulse, are indications for urgent surgical exploration. Hemodynamically stable patients with risk factors including severe cervical injury; anoxic brain injury from hanging; closed head injury with diffuse axonal injury; midface or complex mandibular fractures; marked neck soft tissue swelling; high-risk cervical spine fractures (such as vertebral body subluxation, C1–C3 vertebral body fracture, and any fracture extending into the transverse foramen); or basilar skull fractures involving the carotid canal should undergo initial diagnostic imaging with CTA.[42] Cervical spine assessment should include imaging if the mechanism of injury, the patient's musculoskeletal and neurologic symptoms, or physical exam findings suggest an injury.

Otolaryngologists anecdotally reported a low threshold for initial diagnostic airway evaluation with flexible laryngoscopy to document endolaryngeal findings and establish a baseline for following post-injury changes. Fine cut CT of the neck was used liberally to evaluate patients with suspected laryngeal fractures in theater (see Chapter 29, Management of Acute Laryngotracheal Trauma). All patients with a history of blunt cervical trauma must be monitored closely during the first 12 to 24 hours after injury, when significant edema and airway compromise may develop (Case Study 28-3).[43]

SUMMARY

Orderly initial assessment and management of casualties with penetrating neck wounds following an advanced trauma life support protocol is essential. Casualties who present with signs and symptoms of shock and continuous hemorrhage from a neck wound should undergo immediate surgical exploration. After life-threatening injuries are stabilized, a more focused evaluation of the penetrating neck wound is undertaken. If the platysma is not violated, surgical exploration is not indicated. Asymptomatic casualties with wounds that penetrate the platysma should be evaluated by a surgeon within 24 hours to rule out significant injury to the great vessels, trachea, or esophagus. All patients with symptomatic penetrating neck trauma should undergo neck exploration in the OR. If the patient is stable, CTA may be obtained en route to the OR to help define the surgical approach. If the patient is asymptomatic, evaluation with CTA and possibly panendoscopy in the OR is advised. If the evaluation is negative, the patient should be closely observed. If significant neck injuries are found, neck exploration in the OR is indicated. Casualties with zone I or zone III penetrating injuries, penetrating esophageal injuries, or penetrating laryngotracheal injuries should be transferred to a facility with surgeons skilled in the surgical management of these injuries as soon as possible.

Figure 28-4. Improvised explosive device wounds to right neck and face.

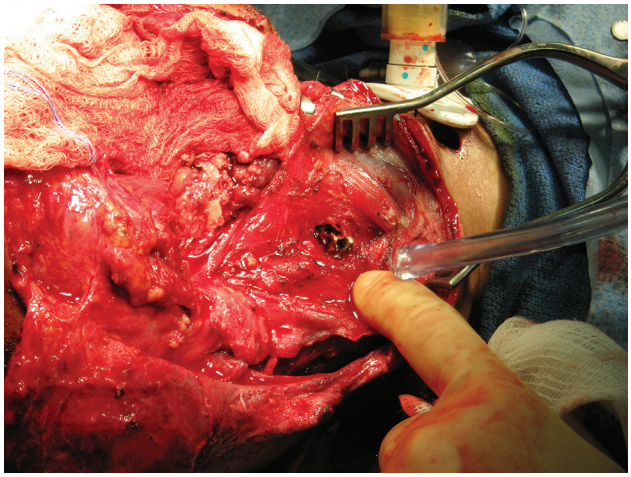

Figure 28-5. Neck exploration through wound with metal fragment in internal jugular vein.

CASE PRESENTATIONS

Case Study 28-1

Presentation

An Iraqi male insurgent in his mid-twenties received a cricothyroidotomy in the field and was aeromedically evacuated to the 332nd EMDG Role 3 hospital after receiving multiple wounds from an IED blast during an Iraqi Police Force action (Figure 28-4). He was admitted in profound shock, with a systolic blood pressure of 70 to 80 mm Hg. Exam in the OR revealed a 5-cm right posterior chest wound medial to the scapula, a 6-cm wound to the posterior right neck, a 14-cm wound of the right upper neck and face with an underlying severely comminuted right mandible fracture, a 4-cm wound to the midline forehead with underlying frontal bone fracture, multiple small fragment wounds to the right flank and right hand, and bleeding from abrasions of the right posterior occipital scalp. Fluid resuscitation and blood transfusion was started, the wounds were packed to control bleeding and urgent exploratory thoracotomy and laparotomy were performed, both of which were negative. The patient's vital signs stabilized in the OR and he was taken to radiology for a head-to-pelvis CTA.

Radiology

Significant findings on the head-to-pelvis CTA were a right anterior and posterior frontal sinus skull fracture and underlying hematoma with midline shift; extensive comminuted open fractures of the right mandible; and a retained metal fragment in the right neck with no flow through the IJ vein. No intracranial metal fragments were found.

Operations

On hospital day 1, the patient underwent exploratory thoracotomy and laparotomy, followed by CT, followed by a craniotomy to evacuate hematoma, followed by neck exploration and repair of right IJ laceration. The neck was explored by extending the cervical wound inferiorly along the anterior

Figure 28-6. Neck wounds after debridement of burns.

Figure 28-7. Planning for pectoralis myocutaneous flap.

border of the SCM and exposing the carotid sheath by retracting the SCM laterally, where a 1-cm metal fragment was found lodged in the right IJ (Figure 28-5). The fragment was removed, the vessels explored, and a 7-mm laceration in the IJ was repaired and covered with SCM. The back and neck wounds were debrided, irrigated, and dressed with saline-dampened gauze.

The patient was returned to the OR on hospital day 3 for repair of the mandible fractures with a mandibular reconstruction plate, closure of the facial wound with a cervical rotation flap, closure of the anterior neck wound, and additional debridement of posterior neck and back skin devitalized secondary to burns (Figure 28-6). On hospital day 6, he was returned to the OR again for transfer of a pectoralis myocutaneous flap into the posterior neck wound, which allowed direct closure of the back wound (Figures 28-7 and 28-8).

Complications

None.

Case Study 28-2

Presentation

A US soldier arrived by aeromedical evacuation after being injured by an IED blast during a fire fight. Exam in the trauma bay revealed an intubated male with a 1-cm stellate penetrating injury in the midline neck below the chin with an expanding right neck hematoma (Figure 28-9). The patient's airway and vital signs were stable.

Figure 28-8. Pectoralis myocutaneous flap in situ.

Figure 28-9. Penetrating neck wound with hematoma displacing larynx and trachea.

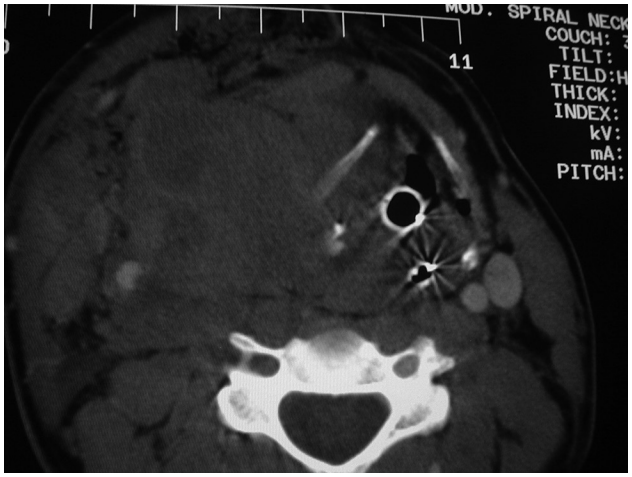

Figure 28-10. Neck computed tomography scan demonstrating hematoma.

Preoperative Workup/Radiology

A CTA was performed en route to the OR that showed a large right neck hematoma surrounding the carotid sheath with evidence suggestive of a common carotid artery (CCA) injury (Figures 28-10 and 28-11).

Operative Plan/Timing of Surgery

The patient was taken directly to the OR from the CT scanner.

Operation

The right neck was explored through a vertical incision anterior to the right SCM. The carotid sheath was opened and the hematoma evacuated, revealing a 7-mm defect in the CCA. The distal and proximal CCA was exposed and controlled with vessel loops (Figure 28-12). A segment of saphaneous vein was harvested from the leg and a reverse saphaneous vein graft was performed after resecting the damaged segment of the artery (Figure 28-13). The patient was extubated in the OR and transferred to the intensive care unit.

Complications

None. The patient was evacuated out of theater and recovered without deficits.

Case Study 28-3

Presentation

A US soldier was brought in by aeromedical evacuation with hoarseness and cervical swelling after sustaining a clothesline injury to the neck (Figure 28-14). He was riding in an exposed position as the gunner in a lead high-mobility multipurpose wheeled vehicle (HMMWV) traveling through an Iraqi town during a mounted reconnaissance patrol mission and caught his neck on a wire suspended between buildings across a road known to be well traveled

Figure 28-11. Neck computed tomography scan demonstrating hematoma with retained metal fragment.

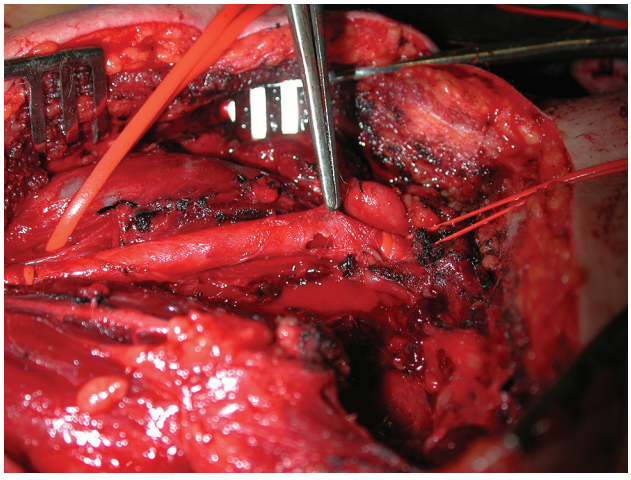

Figure 28-12. Left common carotid artery laceration from improvised explosive device fragment.

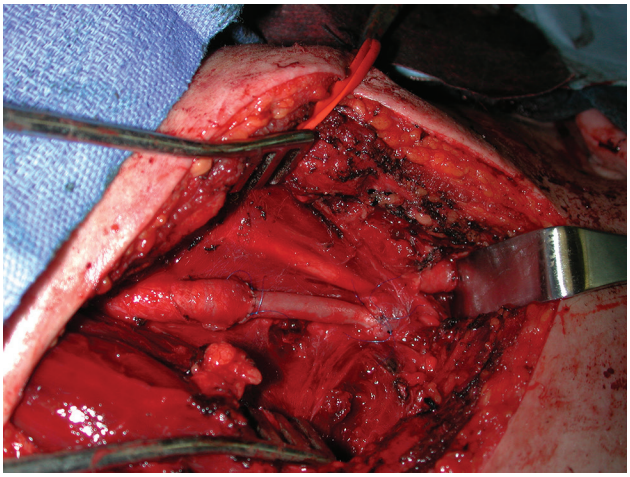

Figure 28-13. Left common carotid artery repair with interposition vein graft.

Figure 28-14. Clothesline injury to neck.

by the coalition forces. Examination in the trauma bay with a nasopharyngoscope revealed moderate laryngeal edema with otherwise normal appearing anatomy and function. He was admitted for observation in the intensive care unit, discharged with gradually improving symptoms after 24 hours, and fully recovered.

Radiology

None.

Operation

None.

Complications

None.

Lessons Learned

The Iraqi insurgents used these suspended wires effectively during the earliest phases of the war. By 2005 HMMWVs were equipped with wire cutters placed in front of the turrets, which eliminated the threat.

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