Chapter 31

MANAGEMENT OF NECK AND SKULL BASE VASCULAR TRAUMA

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INTRODUCTION

Vascular trauma of the neck is often a life-threatening event. As the conduit for the major vessels traveling from the thorax to the cranium, the neck contains some of the most concentrated vascular anatomy in the human body. Throughout history, the military has provided the basis for civilian management of cervical vascular trauma. Today, military combat trauma continues to provide a robust experience; no other environment results in such a high volume of cases. However, surgery for acute combat traumatic injuries is necessarily performed in austere environments and is often characterized by limited access to the technological advancements that dominate civilian practice. A truly modern management strategy, therefore, is best understood through the lens of both military and civilian experiences.

HISTORICAL PERSPECTIVE

Today's head and neck surgeon confronts an enduring controversy that has persisted for over a hundred years: which penetrating neck injuries need to be explored surgically? Permutations of this question include: (*a*) How quickly? (*b*) With what preoperative studies? (*c*) What is the best approach? A historical perspective is necessary to understand the importance of these questions.

Following World War I, surgeons became concerned that the high number of arterial pseudoaneurysms from penetrating cervical trauma was proof that nonoperative management had been pursued too frequently.[1] As a consequence, surgeons in World War II, the Korean War, and the Vietnam War largely followed an edict to explore all penetrating neck wounds. As Fogelman stated in 1956, "Definitive early surgery is the most conservative form of therapy. Expectant therapy is radical in that it results in an inordinately high mortality rate."[2] Fogelman demonstrated a 6% mortality rate for injuries explored within 6 hours and a 25% mortality rate for injuries explored beyond 6 hours.[2]

In 1967, Jones reconfirmed this conclusion, mandating early surgical approach for all neck injuries penetrating deep to the platysma muscle. Importantly, he reported a 39% negative neck exploration rate.[3] Jones reasoned that the concern for missed injury far exceeded the minimal morbidity associated with a neck exploration—he reported no deaths and only one superficial wound infection in 265 cases.[3]

By the 1970s, concern over the high rate of negative neck exploration led surgeons to reevaluate earlier dogma. In 1969, Monson introduced the concept of neck zones, which was recapitulated into its modern form by Roon 10 years later.[4,5] According to this new classification system, stable patients with high or low neck injuries were evaluated with preoperative arteriography. Immediate operative intervention was reserved for patients with injuries to the mid-neck.[4,5] The trend toward a less invasive approach has continued. The advent of improved diagnostic and treatment modalities such as computed tomography angiography (CTA) and endovascular repair techniques have revolutionized the way cervical vascular trauma is managed today.

ANATOMY

The neck has traditionally been described as having three zones as a means to simplify its complex anatomy and to guide the management of traumatic injuries. The difficulty in obtaining proximal or distal control of vascular injuries high or low in the neck is codified in the designation of neck zones. Zone I contains those structures inferior to the cricoid cartilage and superior to the clavicles. Zone II is located between the cricoid cartilage and the angle of the mandible. Zone III includes those structures from the angle of the mandible to the base of skull.[5]

Zone I contains the brachiocephalic artery, subclavian arteries, and the common carotid arteries. The brachiocephalic artery is the first and largest branch off the arch of the aorta. The left subclavian artery and the left common carotid artery arise directly from the aortic arch, while the right subclavian artery and the right common carotid artery originate from the brachiocephalic trunk. In addition, zone I contains the first or preforaminal portion of the vertebral artery; that is, from its proximal source off the subclavian artery to its entrance into the foramen of C2. Veins include the brachiocephalic, subclavian, and internal jugular veins. Injury to zone I has consistently accounted for approximately 20% of all penetrating neck injuries in the civilian literature,[6–8] but has been reported as low as 11% in a military population.[9]

Zone II contains the bifurcation of the common carotid artery at the level of the superior aspect of the thyroid cartilage into the proximal portions of the internal and external carotid arteries. The second and proximal third portions of the vertebral artery are also present in zone II. This zone represents the most frequently injured region of the neck, with rates between 38% and 52% in civilian series and 33% in the military.[6–9]

Zone III of the neck contains the external carotid artery and its branches, as well as the upper cervical portion of the internal carotid artery and vertebral artery. The internal carotid artery enters the skull base at the carotid canal in the petrous portion of the temporal bone, and the vertebral artery enters the skull base at the vertebral canal between the posterior arch of the atlas and the occipital bone. Zone III injuries are the least frequent, varying between 8.5% and 19% of civilian case series.[6–8,10] Military zone III trauma, however, has been reported as high as 33%.[9]

While this classification system is useful, wounds that involve multiple zones are common. Between 16% and 29% of penetrating neck injuries traverse multiple zones, thus complicating the classification and management of these injuries.[6–9]

TYPES OF VASCULAR INJURY AND EPIDEMIOLOGY

Vascular injury following neck trauma is common and may be caused by both penetrating and blunt mechanisms. Major vascular trauma following penetrating neck injury occurs in about 20% of cases.[11] Examples of penetrating neck trauma experienced in the civilian sector include knife injury and gunshot wounds. As the force and velocity of the mechanism of injury increases, more damage is likely to occur; high velocity rifles tend to cause more damage than knife wounds. Damage is caused by the combined effects of both direct and indirect mechanisms, including shearing forces to surrounding structures.

In the modern combat environment, nearly four out of five cases of cervical vascular trauma are caused by blast injury.[9,12] Blast injuries can be classified as primary, secondary, tertiary, and quaternary. Primary injury is the result of a sudden increase in air pressure and tends to affect air-filled structures such as the ears and lungs. Secondary injury, the result of ballistic fragments, is the most common cause of vascular injury and results in a high percentage of penetrating vascular trauma.[13] Tertiary injury, which occurs when the casualty becomes a projectile and strikes other objects, may result in blunt trauma. Finally, quaternary injury is the result of thermal injury from the blast. Examples of blast injury include those resulting from improvised explosive devices, rocket-propelled grenades, landmines, and mortars. These types of injuries are particularly difficult to manage because they almost always cross multiple zones of the neck, may be associated with occult findings, and may obscure radiographs due to retained metallic fragments.

Approximately 60% of cervical vascular trauma affects arteries, and the remaining 40% involves venous injury.[13] The most commonly injured major neck vessels include the carotid artery and the jugular vein. The carotid artery is injured in approximately 50% of cases and the jugular vein in 42%.[9] Vessel injury may take many forms. Intimal flaps, dissection, and partial or complete transection are several of the immediate manifestations of vascular injury. Later developments include thrombosis, arteriovenous fistula formation, and the development of pseudoaneurysms.

A rare but important subset of vascular neck trauma includes injuries to the vertebral arteries, located deep within the neck, which occurs in about 3% of combat casualties with arterial injury. Over half of these injuries involve the second portion of the vertebral artery. In contrast to the anterior neck vessels, the mechanism of injury to the vertebral arteries is fairly evenly split between gunshot wounds and blast injuries.[14]

DIAGNOSIS

In any case of traumatic vascular injury to the neck, the history and physical examination are paramount to diagnosis. The practitioner must always start with a thorough history to characterize the type of injury sustained, estimate the force of the injury, and develop a plan to rule out associated injuries. Often, extensive soft tissue defects are present, particularly in the case of blast injuries. Other serious associated injuries that must be evaluated include those involving the trachea or larynx; as many as 20% of patients require tracheostomy for airway management.[9] Ophthalmologic trauma, including globe rupture, may occur, and nearly half of all cases involve facial fractures or complex ocular trauma.[9] Cervical spinal fractures, spinal cord injuries, and intracranial injuries may also occur. The accurate and timely diagnosis of injuries is predicated on access to appropriate resources, both human and technological. In the setting of a mass casualty, for example, occult cervical vascular trauma may be overlooked when more obvious injuries warrant the immediate attention of the available physicians. Therefore, injuries must be reevaluated at each level of care along the medical evacuation route.

A number of prominent physical exam findings may indicate a vascular injury has occurred. Certainly, a bleeding vessel may result in hemorrhage and subsequent shock physiology. In fact, nearly 30% of patients with cervical vascular injury present with systolic blood pressures less than 90 mm Hg.[6] Contained hemorrhage in the neck may cause hematoma and shifting of the midline neck structures. Active bleeding and expanding hematoma are frequently cited as the two most common presenting signs prompting surgical exploration in both civilian and military trauma.[6,13] Less obvious findings include diminished peripheral pulse pressures, bruits, and neurological compromise.

The importance of identifying clinically significant vascular injury by physical exam alone is critical, especially in the forward combat environment. A number of recent studies have supported this practice, demonstrating that physical exam can be used to rule out significant vascular injury in stable patients. When compared to conventional angiography, physical exam alone has been shown to be 93% sensitive with a 97% negative predictive value.[15]

A special note should be mentioned regarding injury to the vertebral arteries. Although rare, vertebral artery injury is often overlooked because it is associated with few physical exam findings. These injuries rarely present with gross bleeding, but more commonly cause delayed neurological deterioration secondary to thrombosis, arteriovenous fistula formation, and the development of pseudoaneurysms. Due to the redundancy of the posterior intracranial circulation, unilateral vertebral artery injury is symptomatic in only about 20% of cases.[14]

Despite the importance of physical exam, angiography is also a major tool in the diagnostic armamentarium. Traditionally, injuries to zone I and zone III have first been analyzed with angiography as a means of classifying the injury and determining the operative approach. Digital subtraction angiography is considered the gold standard for the preoperative diagnosis of cervical vascular injury and provides the basis against which all other preoperative techniques are compared. Benefits of angiography include its usefulness in defining the operative approach, diagnosing injury, and performing therapeutic intervention, namely through embolization or the placement of stents. Despite these advantages, angiography is an invasive procedure associated with a 1% to 2% complication rate.[5] Furthermore, its use doubles the preoperative time until definitive surgery can be performed.[5]

With improvements in computed tomography, specifically the development of multidetector row CTA (MDCTA), noninvasive radiographic diagnosis of vascular injuries has become possible. When compared to angiography, MDCTA has been shown to be 90% sensitive and 100% specific.[16] Moreover, when compared to an aggregate of all imaging, surgical procedures, and clinical follow-up, MDCTA is 100% sensitive and 93% to 97% specific.[7,8] Combat-derived data reveals similar results, with CTA and physical exam together demonstrating 96.3% sensitivity and 97.2% specificity.[13]

CTA is faster than conventional angiography. However, it has its own inherent limitations and risks. Unlike angiography, CTA is a purely diagnostic modality. Also, CTA may be limited in its ability to visualize the relevant anatomy in the case of retained metallic fragments as commonly occurs with blast injuries. Finally, it too is only intermittently available in deployed settings. Specifically, Role 2 forward surgical teams do not have computed tomography capabilities. Despite these limitations, with the increased use of preoperative imaging on the battlefield, the rate of negative neck exploration has decreased from 39% to 17%.[13]

Other imaging studies include magnetic resonance imaging-angiography (MRA) and duplex ultrasonography. At this time, MRA is unavailable in the combat environment and, even in the civilian environment, is used infrequently due to its high costs and the length of time required for the study. Ultrasound may be available, but is limited by its ability to accurately diagnose injuries only in zone II. Visualization of zone I and zone III injuries is obstructed by the clavicles and mandible, respectively. In addition, correct interpretation of ultrasound is extremely operator dependent.

MANAGEMENT

The initial management of cervical vascular trauma is outlined in Chapter 13, Hemorrhage Management and Vascular Control. In short, initial emergency management should follow the principles of advanced trauma life support, with identification of immediately life-threatening injuries and a focus on airway, breathing, and circulation. The need to triage and identify life-threatening injuries should be the first step in any evaluation of suspected cervical vascular trauma. That is, the first branch point should always be to determine whether the patient is stable or unstable. In the unstable patient, immediate operative management is required. The management of stable patients is more nuanced.

Evaluation

Stable patients should first be evaluated with a thorough physical examination. Certain "hard signs" of vascular injury have been described as a reliable means of diagnosing significant vascular trauma in stable patients. These signs include refractory hypotension and shock, pulsatile bleeding, expanding hematoma, bruit, loss of pulse, and evolving neurological deficit. In contrast, "soft signs" include a history of bleeding at the scene of the injury, stable hematoma, nerve injury, proximity of the injury track, and unequal upper extremity blood pressures. In a prospective study of civilian trauma by Demetriades, 97% of patients with hard signs were found to have clinically significant vascular injury compared to only 3% of patients with soft signs.[6] In combat-related injury, Meghoo demonstrated that hard signs portend a 73% rate of vascular injury.[13] The management of stable patients is further complicated by the fact that numerous extrinsic limitations of care exist on the battlefield. Best practices, therefore, are determined by balancing the need to evacuate casualties to a higher role of care against the attendant risks of delayed intervention.

After physical exam, determination of the affected neck zone should be performed. Injury limited to zone II with associated hard signs usually warrants immediate operative intervention.[2,5,17] For zone I and III injuries, management largely depends on the available resources. Obviously, in the absence of radiographic or endovascular capabilities, open surgical intervention is the only choice. Traditional open approaches to zone I injuries include thoracotomy, sternotomy, and clavicular resection.[18] Zone III injuries may be explored through a lateral cervical or infratemporal approach, but exposure may remain limited by the bony mandible.[19] A transmandibular approach, similar to that used when approaching certain poststyloid parapharyngeal space tumors, is perhaps the best approach to provide adequate access to the skull base.[20]

Repair and Ligation Techniques

Once adequate access has been obtained and proximal and distal vascular control established, the surgeon must decide whether the injured vessel is amenable to repair. Modern combat series reveal that repair is achieved in approximately 20% to 25% of cases.[9,13] Primary repair is ideal, but is limited by its ability to address only small injuries. More extensive injury may require patching or the placement of interposition grafts. Although synthetic grafts have demonstrated equal patency when compared to autologous vein grafts in numerous series for noncombat-related injuries, wounds encountered in the combat setting should be considered uniformly contaminated and more likely to involve postoperative infection.[17] The saphenous vein affords an excellent donor choice because it provides sufficient length and caliber. In addition, it is located remotely from the primary injury site, allowing simultaneous graft harvest.

If the vessel cannot be repaired, ligation should be performed. Ligation is performed in 50% to 75% of cases.[9,13] Venous injuries may be ligated with relative impunity. Ligation provides the most expedient means of managing these low-flow injuries and is rarely associated with significant postoperative complications. In contrast, ligation of arterial injuries is associated with increased risk of neurological compromise, particularly for the common and internal carotid arteries. Ligation of the internal carotid artery results in a stroke rate of approximately 30%.[17]

The ideal modern approach to cervical vascular trauma includes supplementing traditional open techniques with less invasive endovascular procedures. Using stents and intravascular coiling provides important adjuncts. By temporarily stopping hemorrhage, the surgeon is afforded the requisite time needed to perform a vascular repair. This becomes most important in the case of zone I or zone III trauma, where proximal and distal control is most difficult to achieve.

The advantages of endovascular techniques are numerous. When endovascular repair is used alone, general anesthesia can be avoided, thereby circumventing its risks. Perhaps more importantly, the patient's neurological status may be continuously monitored. Used in combination with traditional open techniques, an endovascular approach may be used to improve the surgical view and temporarily stop bleeding.

Typically, access is gained through the femoral artery. Under fluoroscopic guidance, a wire is threaded proximal to the offending region and a balloon is inflated to gain vascular control. In performing these procedures, the surgeon is able to visualize the exact location of the defect. The balloon may then be exchanged for a vascular clamp or left in place. Other possibilities include the placement of either a bare metal or covered stent.[21] In a review of the available literature, Dubose demonstrated an overall patency rate of nearly 80% at 2 years for covered stents and a stroke rate of approximately 3.5% for the treatment of traumatic internal carotid injuries using stents.[22]

Vertebral Artery Injuries

The paired vertebral arteries combine to form the basilar artery that provides the basis for the posterior circulation of the brain. Anastomosis with the anterior circulation occurs via the circle of Willis. In contrast to the anterior circulation, extensive collateralization exists within the posterior circulation; therefore, operative ligation of a unilateral vertebral artery is not typically associated with significant neurological compromise.

As previously stated, vertebral artery injury is rare, but it is associated with a high mortality rate. Nearly one out of three injuries is fatal, which is likely related to associated cervical spinal injury.[14] Unfortunately, because vertebral artery injuries are rare, large case series, particularly in relation to combat trauma, are lacking.

Endovascular techniques are especially useful in managing vertebral artery injuries. Because the vertebral artery travels within the foramina of the transverse processes of the cervical spine, open surgical access is very challenging. Ideal endovascular candidates include patients with low-flow arteriovenous fistulas within the cervical portion of the vertebral artery. Injuries within 2 cm of the vertebral artery origin, within a short distance of the posterior inferior cerebellar artery, or high-flow arteriovenous fistulas are less amenable to endovascular techniques.[23]

An important consideration is the role of anticoagulation and antiplatelet therapy in the management of vertebral artery injuries. Unfortunately, there is little data in the literature on this topic available to guide treatment, and much of the management is based on expert opinion and small case series. Biffl recommends the use of systemic anticoagulation with low dose unfractionated heparin to achieve a partial thromboplastin time between 40 and 50 seconds for all injuries except complete transection. If relative contraindications to systemic anticoagulation exist, he recommends full-dose aspirin daily or clopidogrel 75 mg daily.[24,25]

REPEAT IMAGING

Cervical vascular injuries may not always be readily apparent. Furthermore, limited resources in the combat environment, particularly in the face of a mass casualty, may prevent all injuries from being evaluated immediately. As Fox points out, a "high prevalence of occult injuries discovered [following medical evacuation] . . . underscores the need for a complete re-evaluation upon return to the United States."[9] This applies to both casualties with prior neck exploration and those with suspected vascular injury but no prior intervention.

In a series of patients evacuated to Walter Reed Army Medical Center, all casualties meeting the above criteria were evaluated with some combination of CTA, color-flow duplex scans, or conventional angiography. As previously described, sonography remained of limited use, and CTA was often indeterminate as a result of retained metallic fragments. Conventional angiography, therefore, served as the best means of diagnosing occult injury. Of 63 casualties evacuated with known or suspected cervical vascular trauma, 40 underwent arteriography, and 13 injuries were detected.[9] Approximately half of these injuries required additional operative repair or endovascular embolization.[9] A reasonable approach, therefore, would include repeat angiography in certain patients with prior exploration or suspected vascular injury upon evacuation out of the combat theater.

SUMMARY

The modern approach to cervical vascular trauma synthesizes lessons learned from both civilian and military experiences. It can be simplified into an algorithm with a few fundamental branching points. The first branch point is based on history and physical examination alone and is used to determine whether the patient is stable or unstable. Unstable patients warrant immediate operative intervention. The next branch point involves aspects of radiographic findings, typically in the form of CTA or conventional angiography, in combination with determining which anatomic zone of the neck is affected. Frequent reevaluation of all suspected injuries is necessary throughout the entire medical evacuation process, because cervical vascular trauma may not always be readily apparent. Technological advancements in endovascular repair have afforded surgeons that ability to stabilize and treat injuries that were previously inaccessible.

CASE PRESENTATIONS

Case Study 31-1

Presentation

A 31-year-old Afghan police officer was brought in by helicopter air evacuation to a Role 3 facility after sustaining a gunshot wound to the left neck approximately 30 minutes prior to presentation. During transportation, he had to be seated completely upright to maintain his own airway. Upon arrival in the Role 3 emergency room, the patient was carried in on a stretcher sitting bolt upright, spitting large amounts of bright red blood from his mouth. His oxygen saturation was 98% on a 100% non-rebreather facemask. He was tachycardic with a pulse rate in the 120s and breathing 30 times per minute. On physical examination, he had an obvious left neck zone III entrance wound and right facial exit wound. His tongue was severely swollen to the point that he could not speak or tolerate his oral secretions.

Operative Plan/Timing of Surgery

Stage 1: After less than 1 minute in the emergency room, the decision was made to perform a surgical airway in the operating room. The patient was wheeled 50 ft into the operating room, where an urgent awake tracheotomy was performed with the patient sitting up at a 90° angle. While the surgical airway was being performed, resuscitation was begun, including blood products. The patient quickly responded, and his vital signs normalized almost immediately after his airway was secured and general anesthesia induced. Because of the patient's rapid response to resuscitation and the high cervical injury, the decision was made to perform CTA to better define the extent of injury. At this point, the patient was transported to radiology under general anesthesia to undergo radiographic imaging.

Radiographic Workup

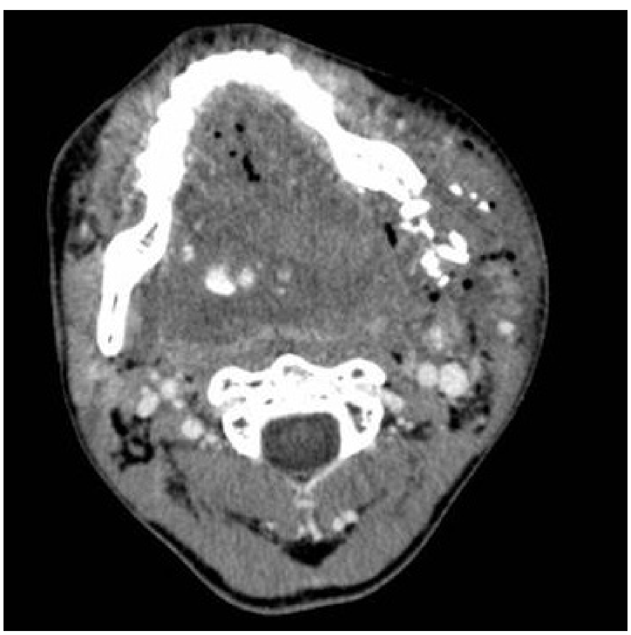

Figure 31-1. Axial computed tomography angiogram demonstrates contrast extravasation in the deep tongue musculature representing active bleeding. Also note the left comminuted mandibular fracture.

CTA demonstrated the bullet path entering at the level of the left mandibular angle, causing a comminuted left mandibular angle fracture, traversing left zone III through the deep tissues of the base of tongue and suprahyoid neck, and exiting through the right floor of mouth and cheek. There appeared to be a large hematoma in the wound with a "blush" indicating active bleeding in the base of tongue (Figure 31-1).

Further Surgery Stages

Stage 2: The patient was brought immediately back to the operating room after completion of the CTA and a left neck exploration was performed (Figure 31-2). After the great vessels were noted to be intact, copious venous bleeding from the floor of mouth and base of tongue was noted as the bullet path was explored (Figure 31-3). After approximately 45 minutes of operative time, definitive hemostasis was not achievable and the patient required further blood products, so trauma packing was performed with laparotomy sponges through both the entrance and exit wounds until active bleeding stopped (Figure 31-4). The comminuted left angle mandibular fracture was also debrided, leaving a 4-cm bony defect. The wound was closed loosely over the sponges and the patient brought to the intensive care unit for further resuscitation.

The next morning, the patient was hemodynamically stable and was returned to the operating room. As the packing sponges were removed, significantly decreased bleeding was noted from the deep wound. Hemostasis was easily achieved with bipolar cautery. The right oral mucosal wound was repaired primarily. The remainder of the wound was closed in multiple layers to minimize dead-space and a passive drain placed. To address the mandible fracture, an external fixation device was placed on the left side (Figure 31-5). Although arch bars would have been preferable, the patient was felt to have inadequate dentition.

Stage 3: Five days after initial injury, the patient was brought to the operating room for mandibular reconstruction. With significantly decreased tongue edema, patient could easily be placed into his premorbid occlusion. The orthopedics team harvested a corticocancellous iliac crest bone graft while the mandibular fracture site was prepared for the graft. A 3.0-mm locking reconstruction plate was used to fix the bone graft into position (Figure 31-6). The patient's tracheotomy tube was removed and he was discharged from the hospital 2 days after the mandibular reconstruction. He remained on a soft diet for 6 weeks. At last follow-up 3 months after injury, the patient was tolerating a regular diet without difficulty.

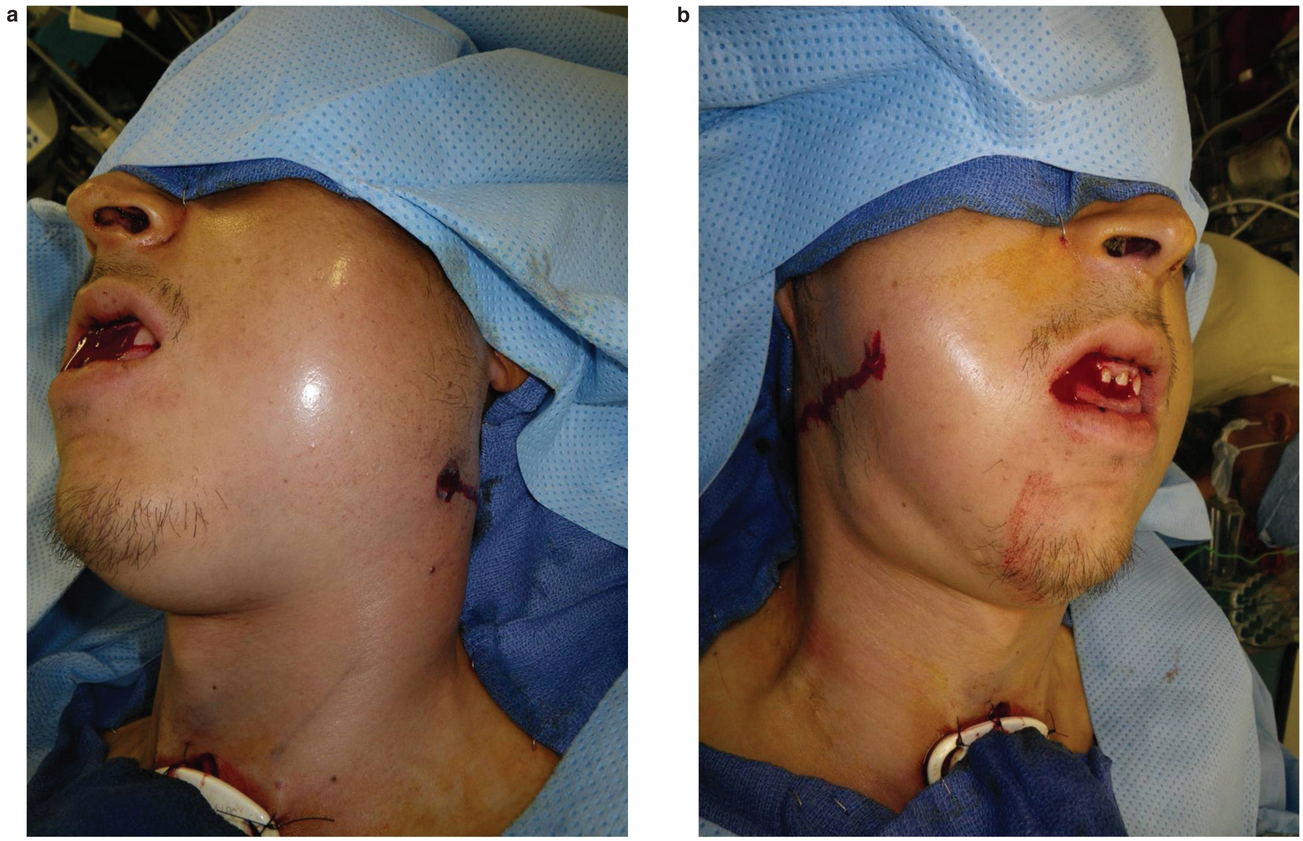

Figure 31-2. (**a**) Left neck entrance wound; and (**b**) right face exit wound. Note the significant tongue edema.

Complications

None.

Figure 31-3. During neck exploration, the path of the high-velocity gunshot wound is demonstrated with a Yankauer suction.

Lessons Learned

High-velocity gunshots are associated with devastating tissue damage that the head and neck surgeon must be prepared to deal with in both the acute and delayed settings. This patient presented with the obvious need for an urgent surgical airway. Because the operating room was less than 50 ft from the trauma bay in the expeditionary combat support hospital where the patient was treated, the surgeon decided to secure the airway in the best possible environment to perform surgery. Performing an awake tracheotomy with the patient upright made the procedure more challenging, but allowed the patient to maintain his own airway and avoid deterioration from an urgent to an emergent situation.

Once the airway was secured, CTA was obtained because the patient was hemodynamically stable and the exit wound was in zone III of the neck. The imaging was helpful because it revealed the deep tongue active hemorrhage, but no great-vessel or skull-base bleeding. During the neck exploration, the cosurgeon, who happened to be a vascular surgeon, recommended "packing off" the wound similar to

Figure 31-4. After initial neck exploration, the wound was "packed-off" with laparotomy sponges to achieve hemostasis and the wound closed loosely over the sponges.

Figure 31-5. External fixation device in place the after second neck exploration on the day following injury.

what is frequently done in the abdomen. This allowed further resuscitation in the intensive care unit and also opened the operating room for other procedures. This nonstandard way of managing penetrating cervical vascular trauma demonstrates the importance of maintaining flexibility and working as a team.

The secondary mandibular reconstruction also demonstrated the importance of working as a team to optimize outcomes. Having the orthopedic surgeon harvest a cortico-cancellous iliac crest bone graft while the head and neck surgeon prepared the recipient site allowed a much faster operative time and preserved critical resources.

Case Study 31-2

***Presentation*:**

A 26-year-old Afghan male was brought to a Role 3 facility by aeromedical evacuation directly from the point of injury. The patient was involved in an improvised explosive device blast approximately 1 hour prior to presentation and suffered injury to his right face, neck, chest, and hand. The patient was intubated

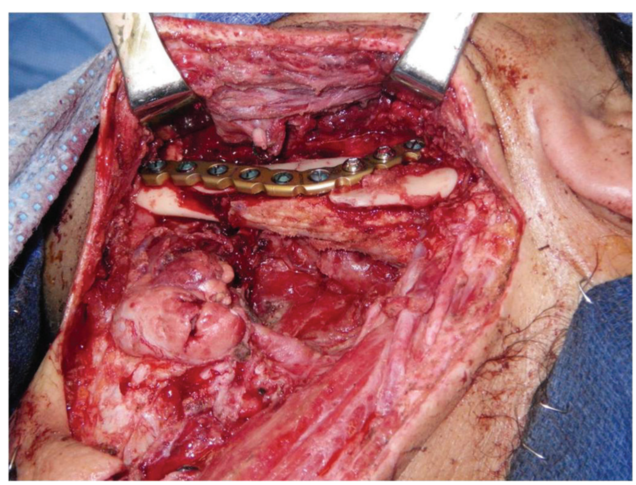

Figure 31-6. Iliac crest bone graft in place during mandible reconstruction.

in the trauma bay with stable vital signs. Physical examination revealed right partial hand amputation and multiple small, deep wounds on the right neck, face, and chest without any obvious severe hemorrhage (Figure 31-7).

Preoperative Workup/Radiology

CTA demonstrated multiple fragments in the right neck with a contour abnormality of the right internal jugular vein suggestive of a hematoma. The scan resolution was limited by the fragments (Figure 31-8).

Operative Plan/Timing of Surgery

The patient was brought to the operating room and underwent a right neck exploration. After proximal and distal control of the great vessels was achieved, a through-and-through injury of the right internal jugular vein was appreciated and the vein ligated. Further exploration of the common carotid artery revealed brisk bleeding from a laceration of the lateral aspect at the bifurcation. A 1.5-cm fragment of bone was removed from the arterial wall and the laceration repaired with 6-0 PROLENE (Ethicon Inc, West Somerville, NJ) interrupted sutures. Further inspection of the penetrating foreign body revealed a distal phalanx likely from the patient's injured hand.

Complications

None.

Lessons Learned

As stated many times throughout this text, "small holes equal big pathology."[26] Although clinically stable, the numerous fragments in the neck resulted in a less than optimal computed tomography scan. Principles of conservative management dictated neck exploration. Although no immediate hemorrhage was apparent upon exploration, the foreign body caused irreparable damage to the internal jugular vein and was embedded in the wall of the carotid artery. If not found during an immediate surgical exploration, this would very likely have resulted in a delayed pseudoaneurysm.

The pattern of injury in this patient, specifically a blast injury at close range affecting the neck, face,

Figure 31-7. Multiple wounds to the head and neck typical of exposure to an improvised explosive device. Right neck exploration revealed a right common carotid artery pseudoaneurysm requiring primary repair.

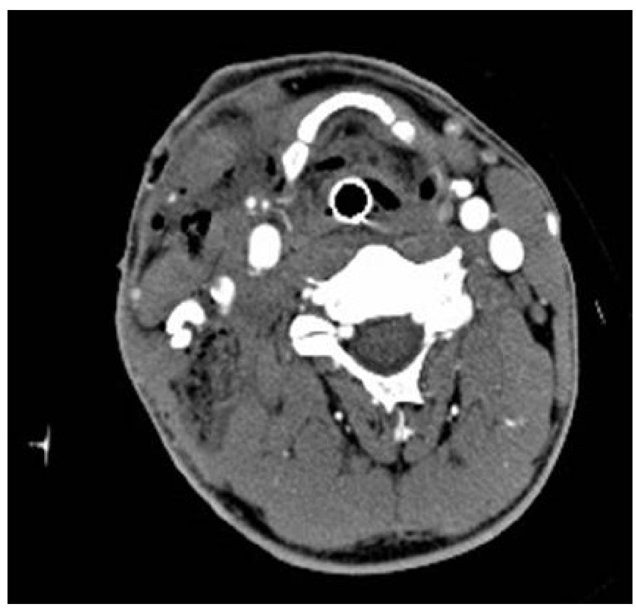

Figure 31-8. Computed tomography angiography showing a bony fragment adjacent to the right internal jugular vein as well as irregularities of the vein and the common carotid artery.

chest, and upper extremities, is strongly associated with manufacturing improvised explosive devices. It is important, therefore, to ensure that any foreign bodies removed be saved as potential evidence. Military investigators often question these patients once they are medically stabilized.

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