INTRODUCTION TO PENE TRATING NECK TRAUMA

Penetrating neck injuries are relatively common in that they occur in approximately 5-10% of all trauma cases. The leading cause of death in a penetrating neck injury is hemorrhage from large caliber blood vessels in the neck. Like many other traumatic injuries, given the urgency of giving appropriate care, it is important for the trauma as well as head and neck surgeons to have a basic knowledge of workup and management of these patients including an algorithm based on current recommendations.

Historically speaking, treatment for any neck trauma that penetrated through the platysma muscle consisted of immediate surgical exploration regardless of area or zone. In recent years, this doctrine of immediate mandatory exploration has been partially abandoned for a more conservative management schema that does not always result in surgery. Proponents of more conservative management cite a high rate of negative findings when mandatory surgical exploration was practiced.

Much of our knowledge of treatment for this condition comes from military experience, specifically in war time. Between the era of the Civil War and World War II, the rate of mortality from penetrating neck injury declined. Yet starting with the Vietnam War and onward an increase of mortality has been seen, presumably from advances in lethality of weaponry and bullets.

PROJECTILES, KNIVES, AND PHYSICS

Bullets from guns comprise the main source of projectile injury to the neck. It is pertinent to understand the basic physical principles of projectile motion to understand patterns of tissue damage. The following equation represents the amount of kinetic energy (KE) produced based on properties of the projectile:

\[ KE = \frac{1}{2} M (v1-v2)^2 \]

where \( M \) represents the mass of the projectile, \( v1 \) is its entrance velocity and \( v2 \) is its exit velocity. Given this relationship then, increasing the mass of the projectile (e.g. bullet) as well as the entrance velocity (\( v1 \)) of this projectile will produce more kinetic energy, and thus damage to the tissue. By the
same token, decreasing the exit velocity (v2) of the projectile/bullet will also increase the damage sustained. Handguns and shotguns tend to produce relatively less damage due to their lower entrance and muzzle velocity compared to rifles which have a much higher muzzle velocity and damage profile. Rifles bullets can travel at up to 2,000 m/s.

An additional variable to be considered regarding the damage sustained by bullet projectiles include the unique types of bullets available to be used. Traditional more simplistic bullets merely created a cavity and wound tract approximately the size of the bullets. Yet modern bullets impact with an array of patterns that can increase the damage profile. Examples of these variations include tumbling, expanding, fragmenting, and explosive bullets.

Somewhat fortunately for the surgeons and patients involved in the penetrating neck injuries, stabbing injuries from shanks, knives, and swords have a much more predictable path of tissue damage compared to bullets. If it is known, the size and shape of the blade used typically correlates to the laceration size found on the neck, and the main unknown variable becomes the depth of injury. Compared to injury by projectiles, stabbing injuries tend to have an increased incidence of subclavian blood vessel damage because of a blade’s tendency to skive over the clavicle. By the same token, unlike projectile injuries, there is a significantly decrease incidence of spinal injury with stab wounds.

**DEFINING THE NECK ZONES AND THEIR ANATOMY**

The neck zones established for penetrating neck injury are as follows, in order of most superior to inferior:

**Zone III:** Spanning the distance of the skull base superiorly to the level of the mandibular angle. Important contents include the distal carotid (external and internal branches) and vertebral arteries, the internal and external jugular veins, the spinal cord, cranial nerves IX, X, XI and XII, and the sympathetic nerve trunk.

**Zone II:** Spanning between the mandibular angle superiorly down to the cricoid cartilage inferiory. Important contents include the mid aspect of the carotid arterial system including the common carotid with bifurcation into external and internal branches, esophagus and hypopharynx, the larynx, the recurrent laryngeal nerve, the vagus nerve (CN X), and the spinal cord.

**Zone I:** Spanning between the cricoid cartilage superiorly and the sternal notch (medially) and clavicles (laterally) at its inferior extent. Important contents include proximal portions of the vertebral and common carotid arteries, the subclavian and innominate arteries, large caliber veins including the subclavian, innominate, and jugular veins, the recurrent laryngeal and vagus nerves, the esophagus and the thoracic duct in the left lower neck.

**BASIC PRINCIPLES OF TRAUMA PATIENT MANAGEMENT**

Despite if an ENT or other specialist is the first-line or subsequent treating physicians for a patient with a penetrating neck injury, it is paramount to remember basic Advanced Trauma Life Support Techniques for proper stabilization and resuscitation of these patients. Primarily, one should address
In regards to the airway, approximately 10% of this patient population has airway compromise from laryngotracheal injury at time of presentation. The airway can be secured in the majority of cases by standard orotracheal intubation, though at times alternate means may be needed including nasotracheal intubation or not uncommonly a surgical airway such as cricothyrotomy or emergent tracheostomy.

In addition to standard ATLS protocol used for any trauma patient evaluated in the emergency setting, some specific tenants should be considered when handling patients with penetrating neck trauma. First, if there is any significant hemorrhaging from a neck wound, one should apply direct pressure to the area. Avoid any deep probing of the neck wounds with fingers because this may dislodge a stable clot and increase exsanguination risk. Attempt to have two large-bore IV placed for fluid resuscitation (18 gauge IV or larger), and if a unilateral subclavian vein injury is suspected, place the IV only on the contralateral side so as to avoid fluid extravasation from the injured side. Lastly, respect the cervical spine and avoid any manipulation of it if possible until it is cleared by imaging and/or exam as being free from injury.

If an emergent surgical airway is required such as if the patient is unable to be orotracheally intubated due to technical difficulty or suspected laryngotracheal injury, then the preferred initial procedure for stabilization is a cricothyrotomy (as opposed to tracheostomy). This is in part due to the more readily palpable and superficial landmarks for this procedure. The basic steps of the cricothyrotomy procedure include the following: 1. With the non-dominant hand, grab and retract the thyroid cartilage superiorly, 2. Just below this make successive vertical incisions through the skin and subcutaneous tissue down to the cartilaginous structures of the airway, 3. Place a horizontal incision in the cricothyroid membrane and place an available endotracheal versus tracheostomy tube into the membranous hole for airway stabilization. This will need to be revised into a formal tracheostomy after stabilization of the patient’s other injuries.

WORKUP AND MANAGEMENT CONSIDERATIONS FOR PENETRATING NECK TRAUMA

As mentioned earlier, the historical management for penetrating neck trauma injuries inevitably included a mandatory surgical exploration of any platysma-violating injury upon patient presentation. This is no longer the standard of care due to a large number of these procedures revealing negative findings (upwards of 50%), potentially adding unnecessary surgical morbidity to the patient’s care.
The above figure was taken from Cummings Otolaryngology (2005) which is representative of a management schema proposed in 1994. The following are major points to be taken from this algorithm:

**Hemodynamic instability/evolving signs of stroke:**

**Key point** here is that if patient with penetrating trauma presents to ER this way then they require mandatory immediate surgical exploration of their neck injury. These patients will have “hard signs” of hemodynamic instability including massive hemorrhage, expanding hematoma, stable hematoma in the presence of hemodynamic instability, hemothorax, hypovolemia, and stroke-like symptoms such as facial droop and hemiparesis.

Note: if you are in a facility that does not have the proper diagnostic equipment needed for selective exploration (interventional radiology, barium swallow), then mandatory surgical exploration is generally required.

**Stable but symptomatic patient:**

They will need exploration in the OR but depending on Zone, one may be able to perform diagnostic work such as CT angiogram prior to needing to go to the OR. For Zones I and III, angiography/workup may be performed first. However for Zone II injury, there is debate to whether surgery may be delayed for proper workup. Historically Zone II was always explored mandatorily, but this may not be necessary based on recent recommendations.

Of note **Zone II** is the most frequently injured zone with 60-75% of penetrating neck traumas coming from this zone. Also it is important to be aware that though multiple structures (including nervous, vascular and digestive) are in Zone II, the management of Zone II primarily hinges on the airway as the primary consideration and the rest are secondary (referencing second figure from Cummings with algorithm).

**Asymptomatic patients:**

Regardless of zone, they may all be managed first with diagnostic workup.
Recent advances in both diagnostic equipment and treatment strategies have somewhat altered the way these patients are managed. The Western Trauma Association published an article in 2013 which was an update on the previously discussed 1994 algorithm. Though several aspects of the new management schema were quite similar to the former one, there were some key difference noted.

First, almost all sections where angiography was proposed as a diagnostic tool have been replaced with CT angiography as a primary diagnostic modality. CT scans are much more readily obtainable and time-efficient than angiography and almost all emergency rooms have this capability.

In this new algorithm the hemodynamically unstable patient is still managed with mandatory surgical exploration. Yet, as an intermediary step to getting the patient to the operating room, a Foley balloon catheter is now recommended as a stabilization tool. Van Waes et al. (2011) recommend taking a standard Foley catheter and placing it into the wound hole in the neck and inflating the balloon so as to attempt to tamponade bleeding coming from major blood vessels until these can be addressed in the operating room properly.

The next significant recommendation made by the Western Trauma Association algorithm includes simple observation without diagnostic workup with serial examination for patient that may have superficial wounds but no suspicion for underlying injury.

For the stable patient where there is high suspicion for injury, the new algorithm has the following recommendations:

1. For **Zones I and III**, all should undergo CT angiography (preferably multi-detector CT angiography, or MD CTA) and pursue further workup such as swallow studies or flexible esophagoscopy and possibly surgical neck exploration versus interventional radiology angiographic treatment.
2. For **Zone II** injuries that are symptomatic, the asymptomatic patient is recommended to have CT angiography performed and the appropriate surgical procedure if positive for injury.
3. If a **Zone II** injury carries symptoms with it, just as in 1994 mandatory immediate surgical exploration is still recommended.

**PREOPERATIVE AND INTRAOPERATIVE DIAGNOSTIC TESTING PRIOR TO SURGICAL EXPLORATION**

Once the physician has decided that selective neck exploration is the best option and further testing is warranted, it is important to know which tests may be best based on the type of injury sustained.

As discussed previously, the diagnostic gold standard for cervical blood vessel injury used to be cervical angiography performed by interventional radiology or vascular surgery via groin access. Not as much for treatment purposes but at least for diagnostic purposes this has started to become obsolete due to a number of factors including more procedure time involved, available staffing, risk of stroke, etc. CT angiography (e.g., MD CTA) has now replaced this as the diagnostic procedure of choice for this type of injury. Sensitivity of injury detection ranges from 90-100% and specificity from 93-100%.
using CT angiography. Signs of vascular injury on CT include hematoma, subcutaneous air down to the carotid sheath, IV contrast extravasation, and missile tracts in close proximity to vital structures. Despite its ability to detect injury, it is important to recognize that CT angiography may be somewhat non-diagnostic secondary to metal or bullet fragments causing streak artifact.

Swallow studies are also a crucial part of the diagnostic workup to detect whether esophageal injury has occurred. Two main contrast materials are routinely used: barium or gastrograffin. Gastrograffin is more water soluble compared to barium, and thus it is a safer agent in the case that there is an esophageal defect. On the other hand, barium is a more sensitive contrast agent to detect a leak, but there is a higher incidence of cervical infection and mediastinitis to occur with use of this.

Esophagoscopy is the next modality to assess for esophageal injury. It is thought that sensitivity of detecting esophageal injury nears 100% when one combines esophagoscopy with swallow study and serial physical exams. A combination of flexible and rigid esophagoscopy may be most accurate for diagnosis as flexible esophagoscopy is generally better to detect mid and distal esophageal injury whereas rigid esophagoscopy better visualizes the proximal esophagus. There is significant redundant mucosa near the cricopharyngeus muscle which the rigid esophagoscope is more adept to evaluate. Finding esophageal injuries early is paramount to patient safety as occult esophageal injury is common, and missed tears may progress to mediastinitis.

In the operating room, before a neck exploration is performed, one may also consider diagnostic workup of direct laryngoscopy and bronchoscopy to evaluate for airway injury. Indications for doing this include hoarseness, vocal cord paralysis, crepitus/tenderness over the larynx, hemoptysis, and subcutaneous emphysema. This may aid in identification of mucosal disruption within the larynx or tracheal lumen.

SURGICAL CONSIDERATIONS FOR PENETRATING NECK TRAUMA

Once the decision has been made for surgical neck exploration, there are several important zone-specific considerations to be aware of:

**Zone I:** This area is difficult to explore surgically due to the bony shield of the clavicles and sternum. Injuries in this zone often involve the great vessels of the neck. There should be a low threshold to involve a cardiothoracic surgeon when injury is low in the neck. If there is a right-sided injury to the great vessels, a median sternotomy is recommended. If it is left sided, a left anterior thoracotomy is recommended. Regardless of surgical intervention, this area carries a relatively high mortality rate of 12%.

**Zone III:** Like Zone I, this area also has a bony shield (the mandible) making it difficult to explore surgically. If surgical exploration is warranted, often a midline or lateral mandibulotomy is needed to access blood vessels at the skull base.

Treatment of Zone III internal carotid bleeding can be particularly challenging to manage given its close proximity to the skull base with poor access for vessel control. Surgical access consists of mandibular dislocation/mandibulotomy with a chance of facial nerve injury. Interventional radiology or vascular surgery is often needed to place a covered stent over the defect. Yet if this is encountered
during exploration, there are methods to temporize the bleeding until a definitive solution can be achieved via gaining proximal control of the carotid and feeding a Fogarty catheter distally in the artery and feeding a vascular shunt such as a Pruitt-Inahara shunt over it to temporarily cover the defect.

**Zone II:** Unlike the other two zones, structures in **Zone II** are much easier to explore surgically. The MD CTA has been shown to be highly sensitive in detecting damage to the aerodigestive tract in this area and not just vascular structures. The incision for access to this area is usually a standard collar incision, but this may be extended along the sternocleidomastoid muscle as needed.

**BASIC MANAGEMENT OF LARYNGEAL/CRICOID INJURY**

Injuries in this area will likely require tracheostomy placement prior to surgical repair for airway procurement. If damage to the thyroid or cricoid cartilage is identified, then open repair with internal fixation is recommended. This is usually done by using 1.0 or 1.3 mm miniplates or stainless steel wires/bolsters. If laryngoscopy identifies disruption of the endolaryngeal mucosa, then a midline thyrotomy may be required with absorbable suture placement to reapproximate the mucosa. If the anterior commissure of the larynx is damaged or if there is an extensive laryngeal fracture that is still unstable after plating, one should consider placing an endolaryngeal stent (this will require tracheostomy placement prior for securing distal airway).

**Management of Tracheal Injury**

Small injuries to the tracheal wall should be repaired primarily, and though tracheostomy is generally recommended, if small enough the injury may not require tracheostomy. One should use 3-0 or 4-0 Vicryl suture to approximate the defect and should be sure to place the suture above and below the cartilage rings at the level of the injury. For larger defects, a tracheostomy will definitely be necessary.

If the tracheal defect is significantly large, one may need to mobilize the trachea for resection and reanastomosis. During this process, one must be careful to avoid recurrent laryngeal nerve injury. Large defects involving at least 5-6 tracheal rings may even require intrathoracic tracheal mobilization. It may be prudent to place lateral retention sutures with 2-0 Prolene during reanastomosis to allow tension free repair of the defect. Consider a 0 Prolene suture placed from the chin to the chest to prevent neck extension post-operatively to ensure proper healing.

**Management of Hypopharyngeal and Esophageal Injury**

10% of penetrating neck trauma patients have sustained a pharyngoesophageal injury. It is very pertinent to recognize that occult esophageal injury may have occurred in up to 25% of asymptomatic penetrating neck injury patients. This should not be missed as it may lead to mediastinitis which can often be fatal. Signs of esophageal injury include crepitus, dysphagia, odynophagia, and hematemesis. If the hypopharynx is solely involved, often times this can be conservatively managed with a nasogastric tube, IV antibiotics, and nothing by mouth.
If the esophagus has an injury, primary surgical repair should be attempted. To do this, expose the esophagus via an incision along the anterior border of the sternocleidomastoid muscle. This incision should be on the same side of the esophageal defect. If it is unclear which side it is on, then place the incision on the left given that the cervical esophagus is generally left of the trachea.

When dissecting down to esophagus, retract the carotid sheath laterally and divide the omohyoid muscle for better access as needed. To better identify the defect, place an esophageal dilator in the mouth which may be seen in the neck. One may also use an NG tube proximally placed with saline or methylene blue flushed through it. During repair, one should utilize a 2-layered closure (mucosa and then muscularis) with absorbable suture such as 3-0 or 4-0 Vicryl. When working in this area, avoid injury to the recurrent laryngeal nerve. After repair, place a penrose or closed drain and have the patient on IV antibiotics for an indefinite period.

**Nerve Injury and Repair**

At the time of neck exploration, if a major cranial nerve or other nerve (e.g. recurrent laryngeal) is found to be severed, one should attempt a primary neurorrhaphy. Typically as first line method, an end-to-end repair is recommended. This should be performed under microscope or loupes magnification. First the nerve should be tediously dissected from its surrounding tissue to free it up for a tension-free repair. Fresh cuts should be made on each of the severed ends, and then a Nylon (size 8-0 up to 10-0) should be used to approximate the ends. This will be performed by placing the sutures 2-5 mm from the cuts ends into the outer epineurium layer of the nerve. Sutures should be placed in a circumferential interrupted manner, needing typically 3-6 total depending on size of the nerve involved.

**MAJOR BLOOD VESSEL REPAIR**

With suspected injury to a major vascular structure in the neck, this generally should be approached via an incision along the anterior border of the sternocleidomastoid muscle. Interestingly, in at least 9% of cases of penetrating neck trauma, the internal jugular vein has been damaged. In general, injured veins (including a unilateral internal jugular) can be safely ligated at time of surgery without any major sequelae. If a large caliber vein like the internal jugular needs ligation, one should double-ligate the two cut ends which includes a suture-ligation. Importantly, if bilateral internal jugular veins have sustained injury, it recommended to attempt to repair at least one in order to avoid post-operative sequelae such as facial edema. When repairing one of these major veins, one should use a running suture pattern with 4-0 or 5-0 non-absorbable suture such as Prolene or Nylon.

Management of major arterial injury in the neck is similar to that of veins with some minor differences. The structures fed by the external carotid artery branches have adequate collateral so these branches may be safely ligated with suture-ligation without issue. However, primary repair should be attempted for injury to the common carotid and the internal carotid arteries.

When repairing these vessels, one should first obtain proximal and distal control of the artery with vessel loops or clamps. The arteriotomy/defect should be closed with a running or a simple interrupted suture pattern. For children with major arterial injury, an interrupted pattern is generally recommended.
specifically to aid in prevention of blood vessel stenosis as the child grows. Suture repair should utilize monofilament non-absorbable suture such as 5-0, 6-0, or 7-0 Prolene or Nylon. For defects that are longer than 1-2 centimeters in length, a venous or synthetic arterial patch placement is recommended. The venous patch can come from the saphenous vein from the groin or ankle. Post-operatively all of these patients should have ICU monitoring for post-operative hematoma, hemodynamic instability (from manipulation of the carotid body), and neurologic status in case of intracerebral embolization or ischemia.

**POST-OPERATIVE MANAGEMENT OF THE PENETRATING NECK TRAUMA PATIENT**

Based on the severity of this type of injury and invasive nature of the surgery, invariably the majority of these patients will need at least 1 night of stay in the ICU for monitoring post-operatively. As mentioned above, if a blood vessel has been repaired, one should be diligent to look for hematoma formation. Patients with repair of esophageal perforation will typically have a drain such as penrose left in place in the neck for at least 1 week while they are kept NPO.

After the 1 week mark, the patient should have a swallow study (may consider gastrograffin first and then if passed, barium). If there is no leak on the swallow study, one can advance the diet to clear liquids and subsequently remove the drain. Inevitably some of these esophageal repairs will lead to esophageal strictures so routine endoscopy with esophageal dilations may be necessary weeks to months after the repair. Lastly, all patients with penetrating injury will need post-operative antibiotics, the length of which varied based on the extent of injury and repair.

**SUMMARY OF PENETRATING NECK TRAUMA MANAGEMENT**

Before encountering a patient with a penetrating neck injury, it is important to have a basic knowledge of projectile types and injury patterns of these weapons in order to qualify the injury and form an appropriate treatment plan. Prior to consideration of specific injury treatment, one should always stabilize the patient in regards to the ABC’s of ATLS management including cervical spine stabilization. As part of the algorithm of diagnosis and treatment a few key points should not be overlooked. First, if the patient is hemodynamically unstable or show any of the “hard signs” of this including evolving stroke, they must bypass diagnostic equipment and go straight to the operating room for exploration, regardless of the zone injured. In contrast with historical recommendations, Zone II injuries do not always require mandatory exploration, though current recommendations suggest they will require this if they have significant symptoms of airway compromise. For most other injuries including asymptomatic Zone II injuries and symptomatic or asymptomatic injuries in Zones I and III, CT angiography is recommended for diagnostic workup prior to exploration in the operating room.
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