Chapter 88: Penetrating Trauma to the Neck

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All penetrating neck wounds are potentially very dangeros and require emergency treatment. The choice of treatment for the stable patient remains controversial; a number of retrospective studies encouraging mandatory surgical exploration and a like number encourage selective surgical attention. For this later category, if clinical presentation allows careful diagnost consideration by frequent observation and medical examination using diagnostic radiology and surgical endoscopy, selected surgical attention may be appropriate. No true randomized prospective studies have been reported (Meyer et al, 1987).

The morbidity of penetrating trauma and the likelihood of successful surgical intervention are important. Knowledge of the physical properties of the penetrating object or weapon can help to determine a treatment plan and predict the risk of injury. The location of penetration also predicts risk and helps in the planning of management (Holt and Kostohryz, 1983).

Physical Properties of Penetrating Objects

Handgun

Civilian handgun injuries traditionally have been caused by projectiles with low muzzle velocity (90 m/sec). An impact velocity of 50 m/sec penetrates skin and an impact velocity of 65 m/sec will fracture bone. This slow velocity projectile has been known to push aside vital structures such as arteries. Many penetrating wounds therefore cause little damage if caused by these small-caliber handguns.

Weapons (guns) are classifed by projectile type and speed as well as caliber (diameter of muzzle bore). The caliber is interchangeable with the designation of the cartridge (0.22 caliber pistol). Handguns are less powerful than rifles and are primarily defensive weapons. They can, however, develop up to 1000 foot pounds of energy. The .44 caliber magnum, which has a large powder charge, can create even more velocity (hypervelocity) and this greater energy ($KE=MV^2$) produces the high end energy. Injury from this gun can cause tissue destruction comparable to that caused by a rifle bullet, a larger projectile.

The yaw of the bullet describes the amount of deflection about the axis of travel and when minimal (not tumbling) and striking perpendicular to a body surface, the bullet will pass through with little energy transmitted and little destruction. A tumbling bullet causes injury in a wide path.

The projectile may follow tissue planes easily and not injure vital structure like arteries, and may be deflected from the bones of the mandible or the cervical spine. This expectation after civilian gunshot wound has recently changed because higher velocity and heavier projectiles are being used in handguns. In all cases, a full inspection of the entire naked body and palpation of the head is necessary to reveal all entrance and exit wounds. This information may be useful in predicting damage.

Low-velocity bullets usually are leadshielded and often leave a radiographic track. A diagnosis based on physical signs of injury, after full and careful organ system evaluation, is often sufficient for these injuries i all presentations are normal; radiographic confirmation or surgical exploration should follow any uncertainty or deterioration of physical signs.

Rifle

Most military rifles have a jacket of strong metal, usually copper, that surrounds a lead projectile. This permits smoother and longer flight because o less drag and less aerodynamic compression. Similarly, because of the lack of deformation these military bullets create a clean hole with a through-and-through wound without a lead track to follow. The M16 military rifle has a bullet that is designed to tuble and, therefore, causes more tissue injury. It is against the terms of the Hague Convention of 1908 for military projectiles to include expanding bullets such as hollowpoint, softnose, or dumdum bullets. These soft-tip bullets expand on contact and cause greater soft-tissue injury. They create a large wound cavity, may not cause an exit wound, and may fragment, with partial projectiles causing injury far from the primary direct path. Hunting rifles use these expanding bullets and, therefore, the civilian wounds caused by these projectiles that are seen occasionally can be more devastating than a comparable wound inflicted by a military weapon.

Velocities of over 610 m/sec are considered high and most military rifles have a muzzle velocity of 760 meters per second. High-velocity missiles not only tear tissue but give energy to surrounding tissue and compress this surround. A cavity up to 30 times the size of the missile may be created and pulsate over 5 to 10 milliseconds, with several waves of contraction and expansion of the tissue (Fackler et al, 1988) (Fig. 88-1). This may explain the finding of a punctured viscus without direct penetration and alert the surgeon to examine the trachea and esophagus even for a bullet wound that is 2 inches distant (Fig. 88-2).

May et al (1976) have calculated the ratio of this velocity to be 65:1 as compared to a handgun, based on the formula that kinetic energy equals mass times velocity. High-energy missiles are not easily deflected and cause significant destruction of tissue in the path of penetration as the energy from the missile is absorbed. Deer rifles fire a projectile designed to mushroom on impact, causing a large amount of tissue destruction within a small area.

The mortality from all high-velocity rifle injuries that are inflicted directly on the neck is significant. Those patients usually do not survive and are not available for study. In view of the expected severity of injury, all known victims of high-velocity rifle injuries that survive to reach the hospital merit strong consideration for surgical exploration. For stable patients angiograms should be considered before surgery, but among the considerations in planning mandatory surgical exploration or diagnostic evaluation is knowledge of the size and velocity of the intruding missile.

Shotguns

Projectiles have a muzzle velocity of 300 m per second, which transmit 10 times the energy of a handgun per unit of mass. The total mass is usually larger but the shot spreads depending on the distance to impact and the choke of the shotgun. A sawed-off shotgun leads to early spraying of the shot. The gauge of the gun determines how much shot can be included in a single shell. The actual shot varies from 00 buckshot designed for deer hunting, which has eight and one half pellets per ounce and a larger tissue impact, through the 12 buckshot, which has 2400 pellets per ounce, little destructive ability, and is used for target shooting. An 8 buckshot with about 400 pellets per ounce is used for shooting small game such as rabbits and birds.

At close range shotgun injuries cause as much damage as rifle injuries. When the distance between the shooter and the recipient is more than 6 meters, the details of gauge, shot, powder load, and the choke of the gun become more important. Radiography is useful for revealing pellets in unexpected locations such as at intracranial, intrathoracic, or intraorbital sites. An MRI may be even more valuable than a CT in these circumstances for the stable patient because metal scatter does not occur.

Miscellaneous

Knife, ice-pick, cut-glass, or razor-blade injuries usually proceed along more predictable pathways; however, there may be more than a single stab wound or more than one stab through what appears to be a single-entry wound. The history of the attack may be of some help to the physician that is, by recognizing whether the blow was overhand or underhand, whether both the attacker and the recipient were standing, and other similar details.

Decisions About Mandatory Exploration

Until World War II the mortality of penetrating neck wounds remained about 15%. It was reduced generally to 4% to 7% by the end of the Vietnam war. The literature explains this improvement occurred through mandatory exploration of all wounds penetrating the platysma. Other improvements in anesthesia, blood transfusion, and general medical care also help explain this improvement.

Classification

The idea of mandatory exploration was heavily recommended for military injuries in World War II and was advocated by Fogelman and Steward in 1956 for civilian injuries. It has been followed from that time until the mid-1980s by most general trauma services at the receiving hospitals of large cities in the USA.

Roon and Christensen (1979) suggested that the neck can be divided into three zones (Fig. 88-3). Zone I is below the cricoid and represents a dangerous area because the vascular structures in this zone connect below the clavicle to the thorax. The bony thorax and clavicle act to protect Zone I from injury as do the other bony structures at the base of the neck. This osseous shield also makes surgical exploration of the root of the neck from above difficult. This usually mandates a combined cervical-thoracic exploration as shown in Fig. 88-4 from Broniatowski and Tucker (1986). Mandatory exploration is not usually recommended for Zone I injuries; angiography is usually suggested to ensure that the great vessels are not injured.

Zone III is located above the angle of the mandible. This area is also protected and is difficult to explore and control because of the skull base and the need to divide or displace the mandible. Similarly, the necessity for craniotomy in exploration and control of high carotid injury in this location makes Zone III treacherous. Injuries to many of the cranial nerves exiting the skull base in Zone III are important to recognize because of their close proximity to the great vessels and the likelihood of injury to an artery if the nerve is injured. Such an abnormal neurologic examination would suggest the need for angiography in the stable patient.

In view of the difficult approaches to Zone I and Zone III, many people recommend that all patients with such injuries who are stable and without evidence of acute airway obstruction, significant bleeding, or expanding hematoma should be evaluated through angiography, with consideration of barium swallow. Zone III injuries also allow frequent intraoral examination to observe edema or expanding hematoma with parapharyngeal or retropharyngeal presentation.

Zone II penetration is the most frequent (60% to 75%) and has created a great deal of controversy in the American literature over the last 15 years (Obeid et al, 1985). There is an ongoing debate about the usefulness of mandatory exploration, and careful examination with selective laboratory and endoscopic tests (including flexible and rigid endoscopy) and angiography is debated.

Initial management

The emergent treatment of all penetrating trauma requires (1) airway establishment, (2) blood perfusion maintenance, and (3) clarification and classification of the severity of the wound. In the emergency department satisfactory control of the airway is established by intubation, cricothyroidotomy, or tracheostomy. Direct transcervical tracheal intubation is safer than oral or nasal intubation when the oral cavity, pharynx, or larynx are traumatized and filled with blood. Particularly after GSW the cervical spine may be unevaluable until the airway is controlled and the direct surgical approach to the airway through the neck often is safer and more rapid. Multiple blind intubation attempts will risk enlarging a lacerated piriform sinus wound and extending it iatrogenically into the mediastinum. Similarly, a tracheal tear may be made worse by extending the neck and distracting proximal and distal segments or by passing the tube through the tear and into the soft tissue distally. The airway must be patent in symptomatic patients and those with evidence of vascular compromise before they undergo angiography.

Large-bore intravenous lines are placed even when the patient is not hypotensive or obviously bleeding so that fluids can be rapidly introduced to the intravascular space if the need occurs. A significant hemorrhage or expanding hematoma, particularly in zone II, will respond to direct pressure and should not be treated by indiscriminate clamping through the wound.

When a pneumothorax is identified via x-ray or physical examination a chest tube should be inserted emergently. In the rare circumstance of an exsanguinating oral hemorrhage, a tracheostomy must be performed immediately and the pharynx must be packed.

In high-intensity trauma hospitals the emergency room usually has an operating theater intended for emergent cases on whom control of a major vessel hemorrhage must be performed immediately, such as after penetrating neck trauma. Under more controlled circumstances the patient can be taken for urgent indications to the operating theater where skin flaps can be made through a wide neck incision from mastoid tip to midway down the neck reaching the midline anteriorly at the level of the cricoid. This incision offers satisfactory exposure of the neck contents and allows selective exploration in an open surgical field.

Diagnostic evaluation

When the patient's stability allows it, an orderly history and physical examination are undertaken and should include a full examination of the unclothed body to look for injuries or exit wounds. In the conscious patient a full neurologic examination should be done at this time and a chest radiograph should be performed as part of the initial workup, when possible. The radiograph should be carefully and selectively examined for hemothorax, pneumothorax, or pneumomediastinum. The latter would suggest a punctured viscus and demands further evaluation. Subclavian vessel injury may be first recognized by an abnormal chest radiograph. All patients should be treated as having potential cervical spine fractures until they undergo radiographic evaluation.

Most centers suggest that local events such as personnel and equipment available for flexible endoscopy or arteriography help to determine the policy of treatment. All tertiary care facilities should be prepared for angiography 24 hours a day with immediate neuroradiologic interpretation available.

A hospital trauma team should include an otolaryngologist as part of the surgical team to help to evaluate and repair the aerodigestive tract and explore the nerves and branches of the carotid artery in the neck. Patients with significant bleeding or those who present with a large or expanding hematoma need immediate attention: either angiography should precede surgical exploration or the patient should be transported immediately to the operating room for exploration.

Several series of cases have shown examples of injuries being misdiagnosed both by angiography and during direct exploration (Noyes et al, 1986). False aneurysms, external carotid branch lacerations, as well as A-V fistulas and fistulas between an artery and a viscus, have all been described despite the presence of sophisticated personnel and experienced examiners.

The debate about the merits of mandatory versus selective exploration is active: Meyer et al (1987) have reviewed their data to suggest that mandatory exploration is appropriate; others (Narrod and Moore, 1984; Obeid et al, 1985; Ratlev, 1990) have used similar data to suggest the advantages of selective exploration. Of patients explored routinely, 50% to 70% have negative explorations with some morbidity and some cosmetic deformity (Bishra et al, 1986; Jurkovich et al, 1985).

Several surgeons have declared their exploratory operations to be the gold standard against which all others should be measured. The rare case of a patient under observation suffering an underdiagnosed hemorrhage with complications is cited to encourage exploration. However, prospective studies have failed to prove that either choice is clearly better. Many surgical trauma teams, including that of Hennepin County Medical Center, which is an ACS level I trauma center, are becoming more encouraged by selective management. The preferred treatment at Hennepin County Medical Center is selective exploration; it is the process of selection and the ability to mobilize expertise rapidly and to make correct and immediate decisions based on those evaluations and interpretations that need further discussion (Fig. 88-5). Table 88-1 rom Miller and Duplechain (1991) shows the accuracy o selective evaluation techniques with the caveat that using rigid and flexible esophagoscopy together can be more accurate than the use of either one alone.

Angiography

Angiography is the most urgently performed evaluative technique because once the airway has been secured by intubation or tracheostomy, hemmorrhage is a dangerous and urgent problem. A positive angiogram may mandate an immediate trip to the operating room, but evaluation of the upper digestive tract in the radiology suite may be useful if time and the patient's condition permits.

The certain indications for angiogram in Zone II injuries include persistent hemorrhage, expanding hematoma, and neurologic injuries compatible with adjacent vascular structure damage (Fig. 88-6) (Hiatt et al, 1984). An example of the latter is sympathetic nerve plexus injury characterized by Horner's syndrome and accompanied by hoarseness, which defines a vocal cord paralysis caused by vagus nerve injury. This neurologic picture suggests that the carotid sheath has been violated, which needs confirmation by angiography as well as frequent close observation to prevent the acute problem of a lacerated carotid artery or the secondary problem of intimal tear or pseudoaneurysm (Fig. 88-7) (Scalfani et al, 1985).

Arteriography can be very accurate with good technique and experienced radiologic interpretation. Patients with negative arteriography and positive physical signs need exploration. However, abnormal neurologic exam suggesting proximate arterial damage may not be confirmed. Observation and treatment o the consequences of the neurologic deficit is sufficient (Ordog et al, 1985) (Fig. 88-8).

Treatment of Vascular Penetration

Zone I vascular perforation requires thoracic surgery attendance in the operating room. Although a low cervical incision may result in suficient exposure, a mediastinotomy extension from this or a formal lateral thoracotomy may be needed.

Zone III injuries at the skull base can be temporized by pressure, but once clarified, access to the injury may require mandibulotomy in the midline as for a parapharyngeal space tumor. A temporary arterial bypass of the carotid artery may be placed until the lacerated or aneurysmic vessel can be approached safely.

All the veins in the neck can be safely ligated to control hemorrhage; if both internal jugular veins are interrupted by the injury an attempt to repair one is appropriate.

All external carotid artery injuries are easily treated by suture ligation because collateral circulation is so good. Common carotid or internal carotid injury in Zone II is explored once the diagnosis is made by an approach along the anterior border of the sternocleidomastoid muscle. In finding the carotid in cases where the vessel is not pulsating (from a hematoma or interruption proximal) external carotid branches may be followed retrograde easily from the facial artery at the submandibular gland or the superior thyroid artery at the superior cornu of the thyroid cartilage.

Techniques of vascular repair (Fig. 88-9) were suggested by Dichtel et al (1984) and by Calcaterra and Holt (1972), who described lateral arteriorrhaphy. They recommend end-to-end anastomosis (when stenosis caused by arteriorrhaphy is a concern) or autogenous grafting, usually for linear stab wounds.

Digestive Tract Evaluation

In the patient with a possible esophageal perforation based on neurologic injury, hematemesis, hemoptysis, dysphagia, odynophagia, crepitance in the neck, or pneumomediastinum, most radiologist recommend gastrographin swallow as a first-order contrast study because barium extravasation into the soft tissues is more toxic. There are mixed reports in the literature (Carducci et al, 1986; Noyes et al, 1986) about which of these methods is more reliable in demonstrating a perforated esophagus or pharynx; a negative gastrographin study should be followed by a barium swallow if a suspicion remains high.

Many studies report using flexible esophagoscopy to relieve the need for general anesthesia during rigid endoscopy. Several authors have reported a missed perforation near the cricopharyngeus; this location, as well as the hypopharynx, is where flexible endoscopy is least satisfactory. Missed esophageal tears (Fig. 88-10) (Spenler and Benfield, 1976) represent most of the delayed injuries and, when they progress to mediastinitis, morbidity and mortality are considerable. Meyer et al (1987) found a significant incidence of missed esophageal injury in their prospective endoscopic, contrast x-ray and subsequent mandatory exploration study. Noyes et al (1986) believe that flexible esophagoscopy is only 86% accurate and that contrast swallow is 90% accurate.

Some surgery services mandate neck exploration for patients who have air in the soft tissues of the neck despite yielding normal endoscopy results. The combination of flexible endoscopy and rigid esophagoscopy to examine the entire cervical and upper thoracic esophagus has been reported. No perforations were missed in those series using both techniques in all patients. If suspicion of a pharyngeal perforation remains unconfirmed by examination or even by exploration, the patient is not fed and is observed for several days. Fever, tachycardia, or widening of the mediastinum on serial chest radiography requires that repeat endoscopy or neck exploration be considered.

The practice at Hennepin County Medical Center has been to perform direct laryngoscopy, bronchoscopy, and rigid esophagoscopy under anesthesia for all penetrating injuries of the neck with air in the soft tissues, hemoptysis, hematemesis, or other suspicious clinical findings. Direct laryngoscopy and bronchoscopy with a rigid endoscope can be combined with flexible airway examination as needed to recognize and stent a lacerated or distracted trachea temporarily. Deinitive treatment is always required for airway interruption and postexamination airway control is mandatory.

If the clinical examination is benign and follow-up examination is done frequently (at least three times every 24-hour shift) by a physician recording his observations, a trial of observation can be attempted. Frequent monitoring of vital signs as well as examination of the neck and the entry wounds by the nursing staff is also crucial to this care plan. An observation period of 48 to 72 hours should be attempted with any change in physical findings or vital signs mandating urgent attention. Most vascular injuries that need attention present within 48 hours. Careful appraisals (Obeid et al, 1985) show that the patient with a negative physical exam and normal radiography and endoscopy will have a negative neck exploration with no significant injury discovered and, therefore, directed observation can be recommended (Fig. 88-11).

Treatment of Aerodigestive Injury

Laryngeal mucosal lacerations from penetrating injury should be repaired early (within 24 hours) as reported by Trone et al (1980) and Schaefer (1991). According to Leopold (1983) the time elapsed before repair has an effect on both airway stenosis and on voice.

Significant glottic and supraglottic lacerations and displaced cartilage fractures need surgical approximation. Endoscopy and CT will differentiate between the cases that need only observation (small laceration, shallow laceration, nondisplaced fracture) from those that require a thyrotomy or open fracture reduction and mucosal approximation. A soft laryngeal stent may be needed for badly macerated mucosa.

Simple tracheal lacerations that do not detach a tracheal ring or encroach on the airway can be repaired without a tracheostomy. More severe disruptions (gunshot wound directly to the trachea) imply more soft tissue injury and a temporary (6-week) tracheostomy either below or through the tracheal injury is safest. Later the stenosis may require sleeve resection but if the stenosis is soft, it can often be managed by a T-tube tracheostomy tube.

Esophageal leaks are very dangerous and must be recognized and repaired. A muscle flap may be interposed over the suture line for further protection (Symbas et al, 1980) and drainage of the wound bed with suction or Penrose drain is needed particularly if neck soiling has occurred. Miller and Duplechain (1991) have shown the value of a muscle flap placed in the bed of a traumatized esophageal and tracheal wound to minimize the risk of a tracheoesophageal fistula (Fig. 88-12).

Summary

Information about the penetrating object or weapon may be useful in creating a treatment plan. Low-velocity handgun wounds are less dangerous and these injuries can be observed more comfortably than injuries caused by high-velocity missiles. A selective exploration plan can be undertaken but must be supported by well done on-site angiography, a combination of flexible and rigid endoscopy, and careful and repeated physical examination of the patient. The contribution of CT and MRI to managing these injuries has not yet been described in the literature.