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Diagnostic Approach to Penetrating Neck Trauma: What You Need to Know

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ABSTRACT

Diagnostic evaluation of penetrating neck trauma has evolved considerably over the last several decades. The contemporary approach to these injuries is based primarily on clinical signs of injury and multidetector computed tomographic angiography (MDCTA). The neck is evaluated as a unit, rather than relying on the surface anatomy zones in which external injuries are seen to guide the workup of internal injuries. This “no-zone” approach safely spares many patients from negative explorations and unnecessary invasive tests. The purpose of this review is to describe an evidence-based approach to the diagnostic evaluation of penetrating neck trauma, including indications for adjunctive testing beyond physical exam and MDCTA.

Keywords: neck injuries; penetrating trauma; diagnosis

Epidemiology

Penetrating neck trauma, defined as injury to the neck that violates the platysma, is a commonly-encountered traumatic injury accounting for upwards of 2% of trauma admissions in the USA (1, 2, 3, 4, 5). Stab wounds account for approximately 40-75% of penetrating neck injuries; gunshot wounds account for 25-45%%; and shotgun wounds up to 4%. (3, 5, 6, 7) Mortality rates range from 2-6%. (3, 8, 9) Although the epidemiology varies geographically (10, 11, 12, 13, 14), the general principles of the diagnostic approach to these injuries do not. Stab wounds cause clinically significant vascular or visceral injuries in 10-20% of cases, and gunshot wounds in about 50%. (2, 9) Arterial injury is found in 15-25% of all penetrating neck trauma (7, 15), and deep venous injury in 16-33%. (16, 17, 18) Aerodigestive tract injuries are found in about 5-18% of penetrating neck injuries, with a predominance of these injuries affecting the trachea, likely due to the anatomic relationship between the trachea and esophagus. (3, 19) Unstable cervical spine injuries are found in 1% of gunshot wounds or fewer and are exceedingly rare with stab wounds. (5, 20)

Anatomy

The first step in the diagnostic approach to penetrating neck trauma is a physical exam, which relies on a practical knowledge of the local anatomy. (21) The caudal boundary of the neck is defined as the sternal notch anteriorly, the clavicles laterally, and the 7th cervical vertebra posteriorly. The cranial boundary of the neck is the inferior border of the mandible anterolaterally and the occipital bone posteriorly.

The neck can be divided into bilateral anterior and posterior triangles based on surface landmarks. (22) The posterior triangle of the neck is bounded by the trapezius muscle posteriorly, the sternocleidomastoid muscle anteriorly, and the clavicle inferiorly. The anterior triangle of the neck is bounded by the sternocleidomastoid muscle laterally, the anterior midline medially, and the inferior border of the mandible superiorly. Historically, the entire neck is divided into three zones based on anterior landmarks (**Figure 1**). (23, 24)

Zone 1: from the sternal notch to the cricoid cartilage

Zone 2: from the cricoid cartilage to the angle of the mandible

Zone 3: from the angle of the mandible to the base of the skull

The internal anatomy of the neck is complex due to the close proximity of vascular, aerodigestive, and neurologic structures. A systematic approach divides key structures into arteries, veins, aerodigestive, neurologic, and musculoskeletal structures (**Table 1**). Although the location of a penetrating wound relative to its surface anatomy does not always correlate with the location of associated internal injuries (25, 26), it can be useful to remember the structures that are contained within each surface anatomy zone. Zone 1 contains the major vessels of the upper mediastinum, the lung apices, lower cervical esophagus and trachea, the thyroid gland, and the thoracic duct. Zone 2 contains the carotid, vertebral, and internal jugular vessels, esophagus, trachea, pharynx, and recurrent laryngeal nerves. Zone 3 contains the distal carotid and vertebral arteries and the distal internal jugular veins. (21)

The initial diagnostic approach to penetrating neck trauma focuses on identifying vascular and aerodigestive tract injuries requiring operative intervention. Arterial injury in the neck presents the life-threatening risks of both hemorrhage and cerebral ischemia. (27, 28, 29) Aerodigestive tract injury presents the risks of airway compromise and sepsis. Direct neurologic injury and spinal instability are also important considerations. However, in penetrating neck trauma, it is exceedingly rare to have an unstable injury with the potential for further neurological deterioration, and therefore it is rare that emergent procedural intervention will be required.

Historical perspective

The diagnostic approach to penetrating neck trauma has evolved in step with technological advances. Before World War II, penetrating neck injuries were generally treated nonoperatively, with an associated mortality of 11-15%. (30) Military experience, subsequently translated into civilian practice, resulted in the practice of mandatory immediate operative exploration for all wounds that violated the platysma. (31) As such, operative exploration was the diagnostic modality used for all penetrating neck trauma. The rationale for this approach was that significant injuries could not be excluded without surgical exploration, and that a delay in diagnosis increased morbidity and mortality. (32, 33) Indeed, the era of mandatory exploration saw the mortality rate associated with penetrating neck trauma decrease to 4-7%. (34) An important limitation to operative exploration as a diagnostic test was the negative exploration rate of over 50%. (34, 35) These negative explorations were associated with a not insignificant complication rate of 1-2% with a real risk of missed injuries which were associated with an increase in the morbidity burden. (17, 35, 36, 37, 38) Because of this, a more selective approach was advocated to spare patients unnecessary morbidity, especially that associated with the more complex exposures of Zone 1 and 3 injuries. (38, 39, 40)

Early selective nonoperative management strategies stratified patients for immediate exploration versus less invasive diagnostic testing according to the surface anatomy zone of their external injuries. Patients with Zone I and III external wounds who lacked immediate indications for operative intervention underwent diagnostic tests including catheter-based angiography, contrast esophagrams, and endoscopy to evaluate for vascular and aerodigestive injuries, thus sparing these patients the morbidity of complex negative explorations. (24, 41) All symptomatic Zone II injuries continued to undergo immediate operative exploration due to the relatively straightforward surgical accessibility of Zone II. (6) A major practical limitation of this approach is that the location of the external wound correlates with the location of internal injury in only 60-80% of cases. (25, 26) Furthermore, both surgical exploration and the full battery of angiographic, radiographic and endoscopic tests are still relatively invasive, as well as being time and resource-intensive. To address these limitations, thorough physical examination was increasingly recognized as a diagnostic modality which could spare appropriate patients from invasive diagnostic procedures. (6, 19, 42, 43, 44, 45) Advances in computed tomography (CT) and its increasing availability led to adoption of multidetector computed tomographic angiography (MDCTA) as an initial diagnostic test for penetrating neck trauma regardless of zone. Together, evaluation of clinical signs followed by MDCTA form the basis of the modern diagnostic approach to penetrating neck trauma.

Modern diagnostic approach to penetrating neck injury

The first step in the approach to penetrating neck trauma is temporary control of external hemorrhage and airway compromise. Bleeding can be controlled with direct pressure or packing. If the pressure cannot be maintained, inflation of a large foley catheter balloon filled with water or saline in the wound tract can be effective, especially for wounds with a narrow external opening (**Figure 2**). (46, 47) Whenever possible, definitive airway control should be performed in the operating room, under optimal conditions, with the surgeon ready to intervene. However, if the patient is unable to maintain their airway, most patients can be intubated orotracheally. (48) For patients with impending airway collapse, the choice of medications should be individualized depending on the injury pattern, ability to oxygenate with bag valve mask, availability of airway adjuncts, and provider skillset. Even in patients who are maintaining their airway on presentation, direct injury to the larynx or trachea and compression or distortion of the oropharynx and upper airway from a hematoma can rapidly progress to loss of airway and render orotracheal intubation difficult or impossible. A low threshold for emergent surgical airway should be maintained. (49) If there is an externally-visible tracheal injury and the patient is awake and alert, the patient should be positioned sitting up. Adequate suctioning and rapid transport to the operating room may allow intubation in a controlled setting, with direct visualization of tube passage past the injury. If there is significant volume loss precluding effective oxygenation, or the patient is unable to maintain their airway, options for immediate airway control depend on the size and location of the injury. Direct intubation of the injury or orotracheal intubation with confirmation of passage of the tube past the injury remain viable options. It is rare for penetrating neck trauma to cause unstable spine injury (5), so in general these emergent interventions can be performed without cervical spinal immobilization.

Following temporary hemorrhage and airway control, patients are next triaged according to clinical signs which predict the likelihood of significant vascular or aerodigestive tract injury (**Figure 3**). The diagnostic approach using clinical signs and MDCTA considers the neck as a unit, rather than as three separate zones. (50) Based on their physical exam, patients are initially stratified into those at high risk for significant vascular and/or aerodigestive tract injury (hard signs); those at intermediate risk who will benefit from further evaluation (soft signs); and patients at low risk of significant injury (no signs) (**Table 2**). (50, 51) For patients with soft signs, MDCTA is the contemporary gold standard screening imaging modality. (52) For those with hard signs, operative intervention is generally required because of the high likelihood of a clinically significant injury. Finally, for those patients that are asymptomatic with no signs, the likelihood of clinically significant injury approaches zero and observation is the mainstay of treatment. An equivocal MDCTA can be followed by additional studies as described below. This approach is associated with a missed injury rate approaching zero (53), a negative exploration rate of less than 10% (53, 54, 55), and avoids invasive testing in most cases.

Expanding upon these three patient presentations of hard, soft and no signs: for those with hard signs of injury, the likelihood of a clinically significant injury is very high and the patient should generally proceed to the operating room for neck exploration. (1) Plain films with skin markers should be obtained preoperatively if feasible to assist with operative planning. However, patients presenting with hemodynamic instability as the only hard sign of injury, who stabilize quickly after initial resuscitation, may benefit from preoperative MDCTA. If the bleeding was from a venous injury, patients are likely to have successful spontaneous tamponade of bleeding and may not require operative intervention. (34) Even in those with an injury requiring intervention, preoperative MDCTA can help with operative planning, and, in select cases may help identify candidates that may benefit from an endovascular solution. (13, 56) A retrospective series using the AAST Prospective Observational Vascular Injury Treatment registry (PROOVIT) database included 110 patients with penetrating cervical vascular injuries and hard signs of vascular injuries. Forty-four percent of patients with hard signs of vascular injury underwent CT scan as the initial diagnostic modality, after which 18% underwent open repair, 7% endovascular repair, and 19% did not require any intervention. (56)

Soft signs predict vascular injury requiring intervention in about 16% of patients, and all of these patients should undergo MDCTA for further evaluation. (57, 58) Clinical signs followed by evaluation with MDCTA has a sensitivity of 90-100% for vascular injury and specificity of 98-100%. (52, 53, 59)

Patients with no clinical signs of injury are very unlikely to require intervention. The sensitivity of physical exam for detecting injuries requiring intervention was 100% in a large prospective study with a mean of 3 days of inpatient observation. (53) In general, the available evidence supports discharging these patients from the emergency department. (57) However, the number of asymptomatic patients in studies evaluating the accuracy of diagnostic algorithms is relatively small; follow up to evaluate for missed injury in the discharged population is limited; and MDCTA is a ubiquitous and low-risk test. Depending on the practice environment in which you work, a reasonable option is to obtain MDCTA for asymptomatic patients in order to expedite discharge, especially in the setting of transcervical or ballistic injuries which have a higher rate of significant internal injury. (57)

Characteristics of MDCTA for penetrating neck injury

MDCTA is the preferred diagnostic modality for evaluation of penetrating neck trauma. A clear advantage of MDCTA over catheter-based angiography and endoscopy is that the surrounding venous and musculoskeletal structures and wound tract are also imaged. MDCTA has reduced radiation and contrast loads compared to conventional angiography. This technology is available in most centers, and uses peripherally-administered contrast, without the need for an interventional radiology team to be called in. If the patient becomes unstable, the CT can be truncated at a moment's notice, allowing the surgeon immediate access to the patient. Limitations of MDCTA include artifact and beam hardening from metal fragments, dental amalgams, or orthopedic hardware; incorrect contrast bolus timing; and the potential for motion artifact. (16)

For diagnosis of vascular injury, the sensitivity of MDCTA is 90-100% and the specificity is 97-100%. (59, 60) Direct signs of arterial injury on MDCTA include dissection, intramural hematoma, pseudoaneurysm, occlusion, transection, and arteriovenous fistula. (22) Indirect radiographic signs include perivascular hematoma, fat stranding, gas, or foreign body adjacent to the vessel (**Table 3**). (61) Veins are the most frequently injured structures in penetrating neck injury. (17, 18) However, most of these injuries can be managed nonoperatively. (62, 63)

For the diagnosis of aerodigestive injuries, the sensitivity of MDCTA is generally reported in the range of 92-100%, with specificity of 90-100%. (60, 64, 65, 66) However, MDCTA often does not directly demonstrate aerodigestive injury, but may show suspicious secondary findings such as air adjacent to the trachea or esophagus. Skin markers at all external wounds should be used for MDCTA to allow assessment of the wound trajectory and its relationship to aerodigestive structures. Just as obvious wall defects or tracts clearly entering the aerodigestive structures on MDCTA are positive indications for operative repair, less obvious findings such as proximity of the tract without clear violation, or small amounts of peri-esophageal air, are positive indications for further workup. Missed esophageal injury rates may be reduced by targeted testing or exploration of patients with high-risk wound trajectories, that is those with trajectories violating the suprahyoid deep neck spaces and infrahyoid visceral space. (65) Indeterminate findings, such as a small amount of adjacent air without obvious involvement of the structure, remain indications for additional testing as described below.

Shotgun injuries

Shotgun injuries deserve special consideration, as the artifact from retained metal fragments limits the utility of MDCTA. The damage caused by shotgun wounds depends on the distance from muzzle to patient, the shotgun characteristics, and type of shell used. The majority of injuries seen at most US trauma centers will be from a shell containing multiple pellets. At close range, the individual pellets strike the victim as a single focus of energy, discharging kinetic energy similar to a high velocity missile. (67) The same holds true for those who have been injured by a shotgun slug. At long range however, the individual pellets can disperse significantly. This results in lower energy impact, but also causes numerous retained metallic fragments scattered over a large area. This causes substantial artifact on CT scan, precluding effective diagnostic evaluation (**Figure 4**). These injuries are relatively low energy, but present a difficult diagnostic challenge. The first step for patients who have sustained a shotgun injury remains MDCTA. If the artifact from foreign bodies precludes accurate CT evaluation, patients should undergo diagnostic workup with traditional catheter-based angiography and endoscopy. In this patient subset, a detailed ultrasound evaluation may also be complementary to the angiography.

Indications for adjunctive tests:

Following physical exam and MDCTA, additional diagnostic testing may be indicated for patients with indeterminate CT findings (**Table 4**). Adjunctive diagnostic workup should be pursued expeditiously to avoid the increased morbidity associated with delayed repair. (68)

Diagnostic catheter-based angiography is indicated in stable patients with indeterminate CT scans concerning for vascular injury, as well as for patients requiring therapeutic angiography and endovascular repair. Diagnostic catheter-based angiography has a sensitivity of close to 100% and specificity of 95-100% for arterial injury after penetrating neck trauma. (9, 69) A benefit of diagnostic angiography is the ability to embolize or stent appropriately-selected injuries during the same procedure. Drawbacks of angiography in the neck include a risk of stroke, as well as the need for arterial access with its potential for access site complications, and a larger contrast and radiation load than MDCTA. (59)

Ultrasound has been evaluated for the diagnosis of penetrating neck trauma, with a sensitivity of 91-92% and specificity of 98-100% for vascular injury. (3, 60) However, its use is limited in Zones 1 and 3, and it does not reliably assess surrounding structures. It also requires a skilled ultrasonographer, which may not be available at all hours, and it can be limited by overlying soft tissue trauma or dressings. (60)

A combination of esophagoscopy, contrast swallow, bronchoscopy, and direct laryngoscopy is indicated in stable patients with indeterminate CT scans concerning for aerodigestive injury. Endoscopy may also be used intraoperatively to enhance the accuracy of operative exploration. Although early studies showed that flexible esophagoscopy had a relatively low sensitivity for esophageal injury, more recent data indicates that the sensitivity for esophageal injury is as high as 96-100%, with a specificity of 92-100%. (9, 70, 71, 72, 73) Laryngoscopy has a sensitivity of 87-92% for laryngotracheal injury, rising to 100% when combined with bronchoscopy, and a specificity of 85-100%. (9) Drawbacks of endoscopy include the invasive and resource-intensive nature of the tests. Despite these limitations, panendoscopy with esophagoscopy, laryngoscopy, and bronchoscopy remains the gold standard to rule out oropharyngeal, hypopharyngeal, laryngotracheal, and esophageal injuries. (60)

Contrast evaluation of the esophagus can be used as a complementary imaging modality for the equivocal endoscopic exam. (72) Water-soluble contrast is typically used first, as the risk of mediastinal fibrosis from contrast leak is less with water-soluble than barium contrast if the injury extends down into this region. (74) However, water-soluble contrast esophagrams are less sensitive and may miss 15-22% of esophageal injuries. (75) A confirmatory barium contrast esophagram is generally indicated in patients with a negative water-soluble contrast esophagram, balancing the risks of missed injury with the risks of mediastinal inflammation and fibrosis due to barium leakage. (72) Water-soluble followed by barium contrast esophagram has a sensitivity of 78% and specificity of 100% for the diagnosis of esophageal injury. (76) Drawbacks of contrast esophagography are that it requires an awake and cooperative patient, is insensitive for oropharyngeal and hypopharyngeal injuries, and carries the risks of contrast aspiration and mediastinitis. (75, 77) CT esophagography, which also requires administration of oral or nasogastric tube water-soluble contrast, is an alternative modality with a sensitivity of 59-100% and specificity of 80-100% for esophageal injury. (76, 78, 79)

Magnetic resonance imaging (MRI) has no role in the initial diagnostic workup of penetrating neck trauma. However, in stabilized patients whose urgent interventions are complete, it is commonly used to evaluate for spinal cord, brachial plexus, and ligamentous injuries, as well as laryngeal cartilaginous injuries. (60)

Conclusions: The modern diagnostic approach to penetrating neck trauma considers the neck as a single unit and is based on clinical signs and high-quality CT angiography, followed by additional testing if CT is nondiagnostic. This approach is associated with a low negative exploration rate, a very low missed injury rate, and avoids invasive testing in most cases. Patients with hard signs of injury should generally undergo immediate neck exploration. In this patient subset, CT angiography may be considered for patients with normalized hemodynamics after initial resuscitation in order to facilitate operative planning. All patients with soft signs of injury should undergo CT angiography. For those patients with no signs of injury, the likelihood of an occult clinically-significant injury is exceedingly low, and the yield of CT is likewise low. However, depending on the practice pattern of the individual trauma center, CT may expedite discharge planning. An awareness of the limitations of MDCTA is important. One of the most common concerns is artifact in those with retained metallic fragments. In these patients, as well as those with an equivocal CT, the traditional complement of imaging, including a targeted combination of catheter-based angiography, contrast esophagram and endoscopy, can be used as a complementary diagnostic adjunct.

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FIGURE LEGENDS

Figure 1. A. Anterior surface anatomy delineating zones of the neck. **B.** Surface anatomy zones of the neck projected onto internal structures. **C.** Vascular structures in the anterior triangle of the neck. **D.** Anatomic relationships of aerodigestive structures in the neck.

Figures 1A, C, D: Reproduced with permission from Demetriades D, Inaba K, Velmahos G, eds. *Atlas of Surgical Techniques in Trauma*. 2nd ed. Cambridge University Press; 2020. Figure 1B: Figure concept inspired by Borsetto D et al. *Penetrating neck trauma: radiological predictors of vascular injury.* Eur Arch Otorhinolaryngol. 2019;276(9):2541-7.

Figure 2. Temporary tamponade of penetrating neck injury using a foley balloon filled with water or saline.

Figure 3. Updated Western Trauma Association Algorithm for Diagnostic Approach to Penetrating Neck Trauma.

Figure 4. Shotgun injury. **A.** Shotgun injury to face and neck. **B.** MDCTA is limited by substantial artifact from retained pellets. **C.** Catheter-based angiogram of the carotid artery in the same patient allows evaluation for vascular injury by obtaining multi-planar views of the vessel.

Figure 1a

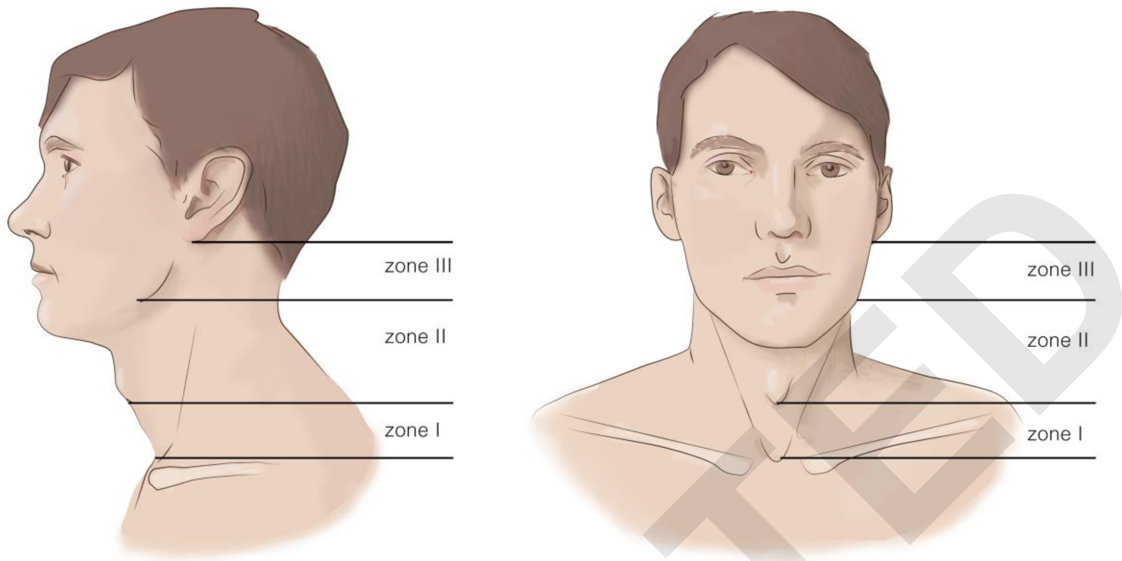

Figure 1b

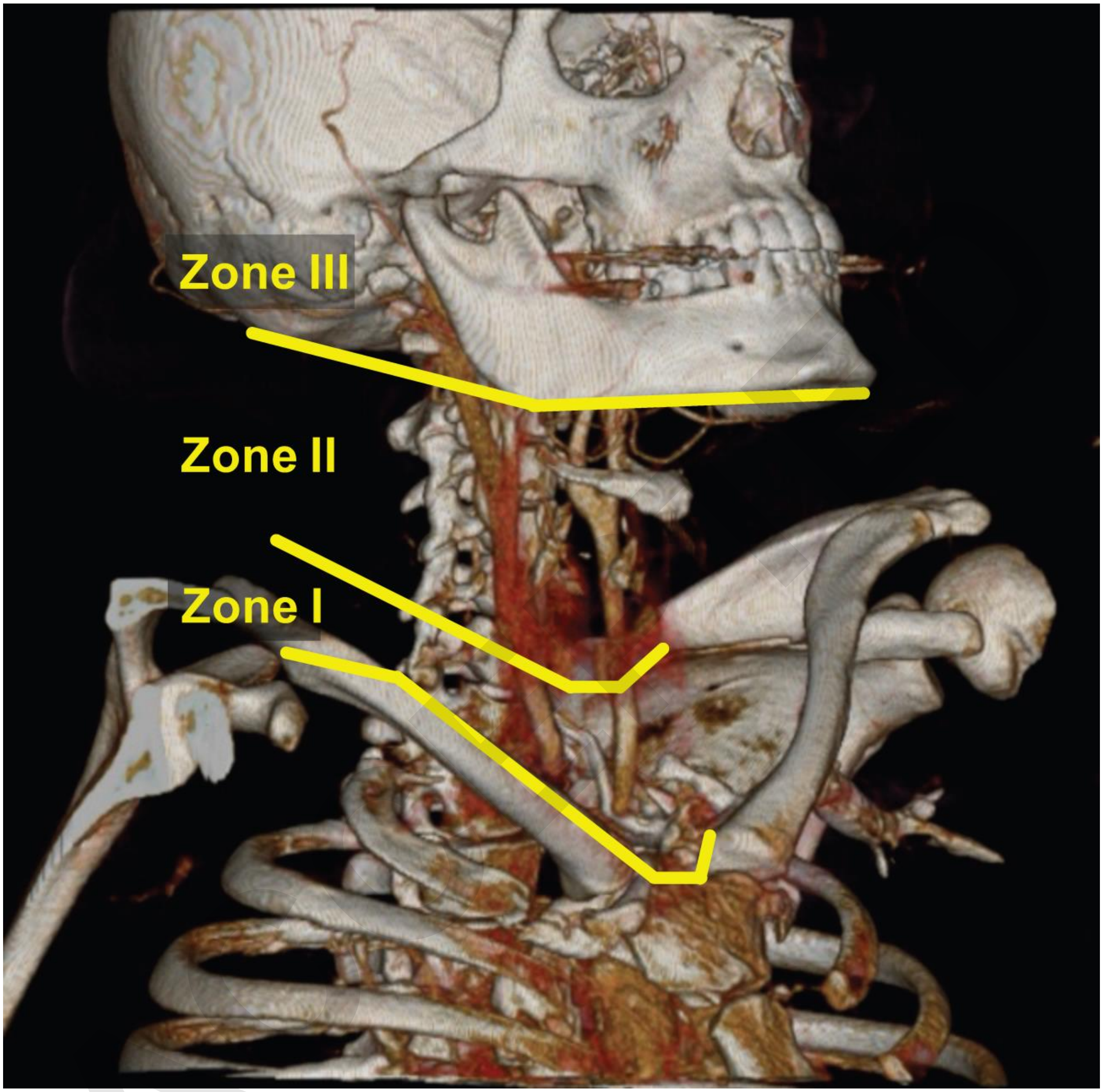

Figure 1c

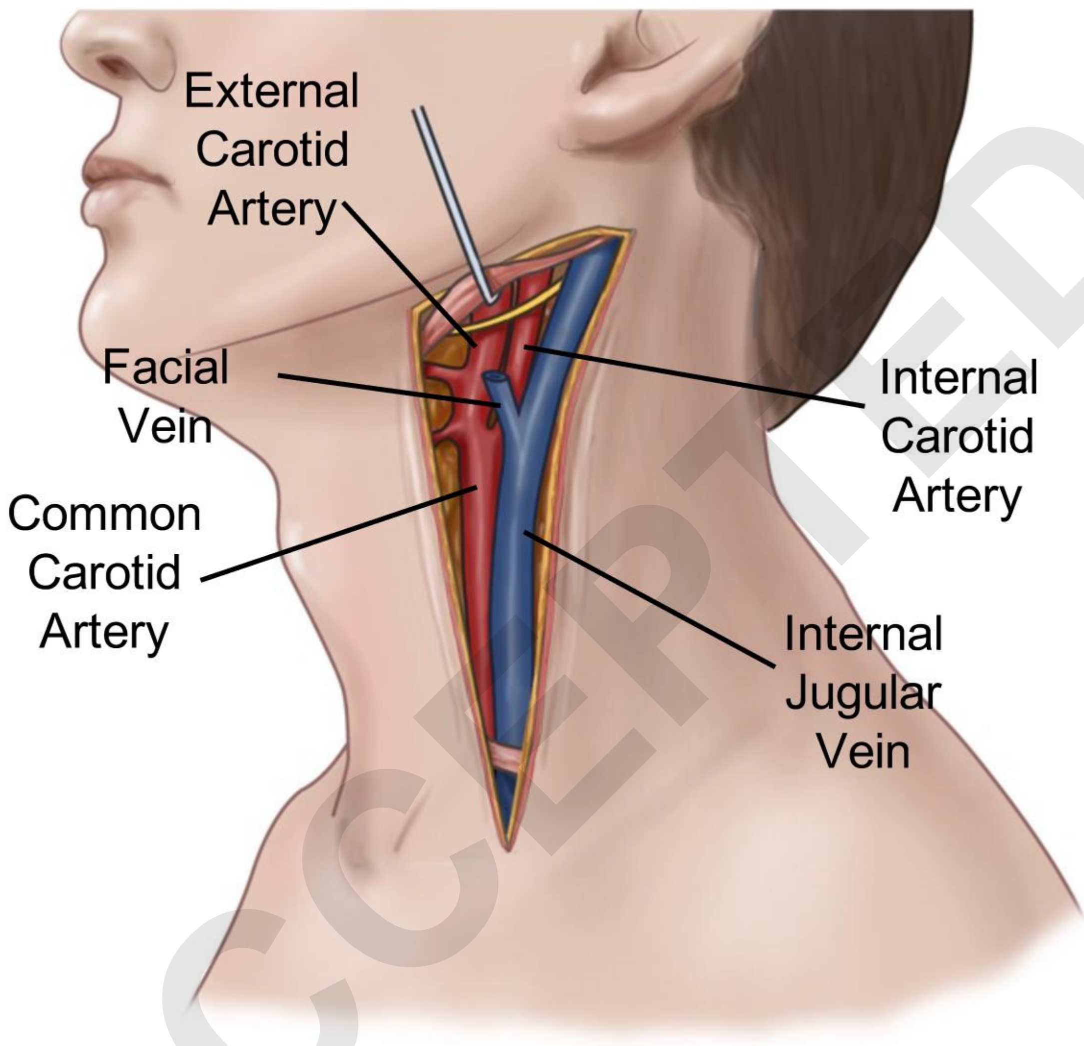
External Carotid Artery
Facial Vein
Common Carotid Artery
Internal Carotid Artery
Internal Jugular Vein

Figure 1d

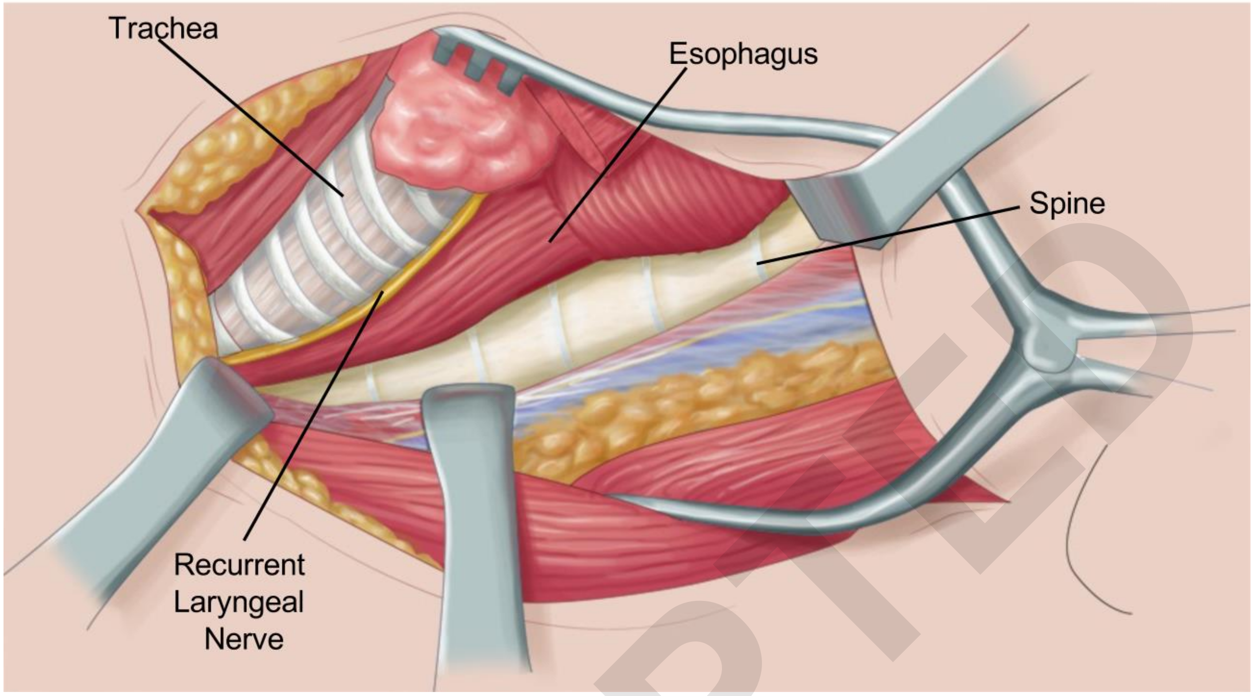

Figure 2

Figure 3

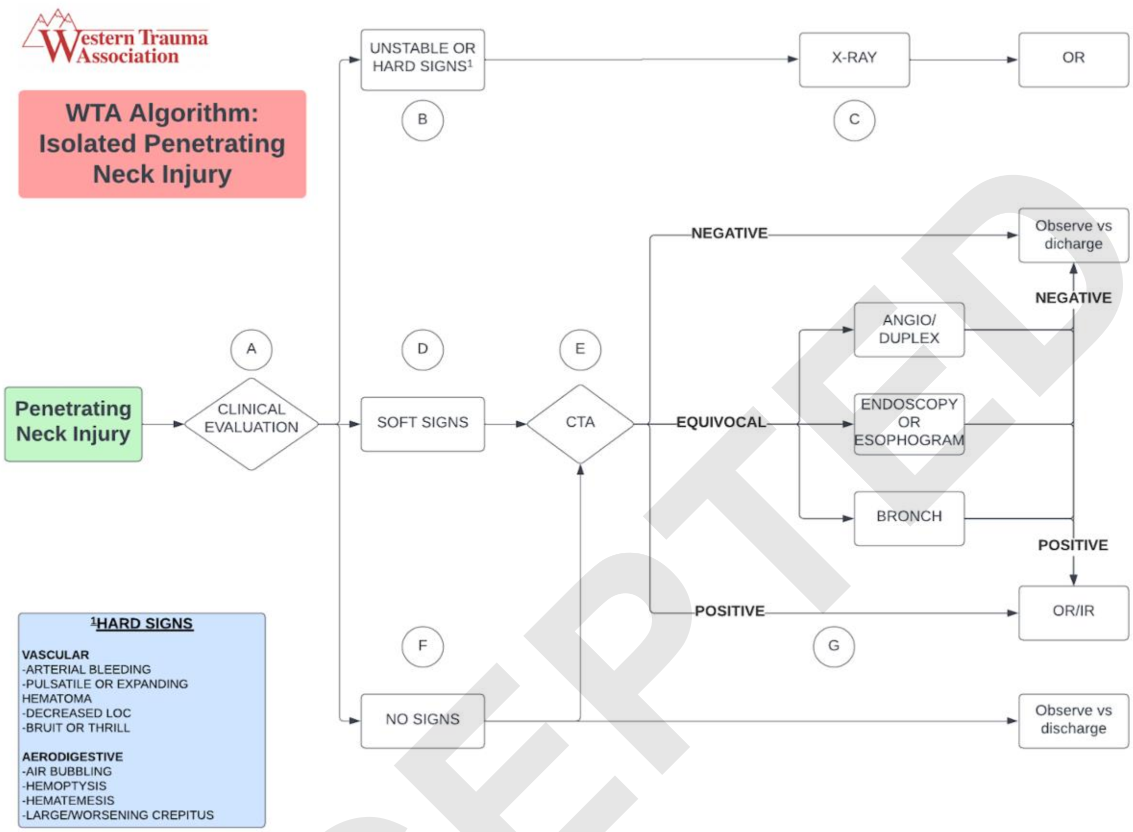
Western Trauma Association
WTA Algorithm: Isolated Penetrating Neck Injury
Penetrating Neck Injury
A
CLINICAL EVALUATION
UNSTABLE OR HARD SIGNS1
B
X-RAY
C
OR
D
SOFT SIGNS
E
CTA
NEGATIVE
Observe vs dichage
NEGATIVE
ANGIO/ DUPLEX
EQUIVOCAL
ENDOSCOPY OR ESOPHOGRAM
BRONCH
POSITIVE
POSITIVE
OR/IR
F
G
NO SIGNS
Observe vs discharge
1HARD SIGNS
VASCULAR
-ARTERIAL BLEEDING
-PULSATILE OR EXPANDING HEMATOMA
-DECREASED LOC
-BRUIT OR THRILL
AERODIGESTIVE
-AIR BUBBLING
-HEMOPTYSIS
-HEMATEMESIS
-LARGE/WORSENING CREPITUS

Figure 4a

Figure 4b

Figure 4c

Table 1. Anatomic structures relevant to penetrating neck trauma.

	Structure
Arteries	• Common, internal, and external carotid arteries • Subclavian arteries • Innominate artery • Vertebral arteries
Deep veins	• Internal jugular veins • Subclavian veins • Innominate veins
Aerodigestive Structures	• Trachea • Esophagus • Pharynx • Lung apices • Thoracic duct • Salivary glands
Nerves	• Vagus nerves • Phrenic nerves • Recurrent laryngeal nerves • Cranial nerves VII (cervical and marginal mandibular branch); IX-XII • Brachial plexus • Sympathetic chain
Musculoskeletal	• Cervical spine and associated musculature

Table 2. Hard and soft signs of injury relevant to penetrating neck trauma. (22, 58, 19, 57)

	Vascular	**Aerodigestive**	**Neurologic**
Hard signs:	• Refractory shock • Severe or pulsatile hemorrhage • Large or expanding hematoma • Audible bruit • Palpable thrill	• Airway compromise or stridor • Wound bubbling • Significant subcutaneous emphysema • Major hematemesis • Massive hemoptysis	• Remote neurologic deficits (suggestive of cerebral ischemia from vascular injury)
Soft signs:	• Small/stable hematoma • History of bleeding or hypotension • Active venous ooze • Pulse or systolic blood pressure discrepancy	• Hoarseness/voice changes • Odynophagia • Dysphagia • Mild subcutaneous emphysema • Minor hematemesis • Minor hemoptysis	• Local neurologic deficits suggestive of direct injury

Table 3: Direct and indirect radiological signs of vascular injury on CTA. (61)

Direct signs of vascular injury	Indirect signs of vascular injury
Vessel transection	Perivascular hematoma
Partial or complete occlusion	Perivascular fat stranding
Active bleeding	Perivascular gas
Pseudoaneurysm	Foreign body or bone fragments in close proximity to vessel
Intimal injuries	
Dissection	
Arteriovenous fistula	
Luminal caliber change	

Table 4. Sensitivity and specificity of diagnostic modalities for clinically-significant injury requiring intervention in penetrating neck trauma.(3, 9, 16, 19, 34, 43, 53, 57, 59, 60, 61, 64, 69, 71, 72, 73, 76, 78, 80)

	Vascular		**Aerodigestive**	
	Sensitivity	**Specificity**	**Sensitivity**	**Specificity**
Physical exam	43-97%(43, 45, 53, 61)	80-99%(45, 53, 61, 80)	80-100%(19)	75%(19)
MDCTA	90-100%(16, 53, 57, 59, 60, 61)	97-100%(16, 57, 59, 60, 61)	92-100%(64)	90-100%(64)
Angiography	100%(9, 69)	95-100%(9, 69)	NA	NA
Ultrasound	91-92%(3, 60)	98-100%(3, 60)	NA	NA
Esophagoscopy	NA	NA	96-100%(71, 73)	92-100%(71, 73)
Esophagography	NA	NA	78%(76)	100%(76)
CT Esophagography	NA	NA	59-100%(78)	80-100%(78)
Bronchoscopy/ Laryngoscopy	NA	NA	87-100%(9)	85-100%.(9)

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Acute Care Surgery

CONFLICT OF INTEREST DISCLOSURE FORM

Based on ICMJE Form

Date: 2/7/2024

Your Name: Kenji Inaba, MD

Manuscript Title: Diagnostic Approach to Penetrating Neck Trauma: What You Need to Know

Manuscript Number (if known): JT-S-24-00177

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		Reducing exsanguination via In-Vivo expandable foam. Grant # W81XWH-15-C-0147, DoD, Site Principal Investigator, 2023 Total Costs of Study: $407,283; Direct Cost: $323,241	
		Evaluation of a novel hemostatic agent for junctional trauma (PhoXStat). Grant #: W81XWH1820050, DoD, Site Principal Investigator, 2023 Total Costs of Study: $100,650; Direct Cost: $61,000	
		Cold stored platelet early intervention trial (CriSP-HS), Grant #: W81XWH-16-D-0024 W81XH19F0494, DoD, Site Principal Investigator, 2020-ongoing (2023) Total Costs of Study: $324,000; Direct Cost: $257,143	
		Non-Invasive Monitoring of Traumatic Brain Injury Progression using the Infrascanner (MOBI-1 Trial), Grant #: W81XWH-15-9-0001, DoD, Site Principal Investigator, 2021-ongoing (2023) Total Costs of Study: $100,800; Direct Cost: $80,000	
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10	Leadership or fiduciary role in other board, society, committee or advocacy group, paid or unpaid	☐ **None**	
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		Director, American Board of Surgery, Trauma, Burns, Surgical Critical Care Board 2017-2023	
		Region Chief, Region IX American College of Surgeons Committee of Trauma, 2019-2025	
		Chair, American Board of Surgery, Surgical Critical Care Continuing Certification Examination, 2021-2023	
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Date: 2/7/2024

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Manuscript Number (if known): JT-S-24-00177

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14	Family Disclosure. Disclose any financial associations involving a spouse, partner, or children	☒ **None**	

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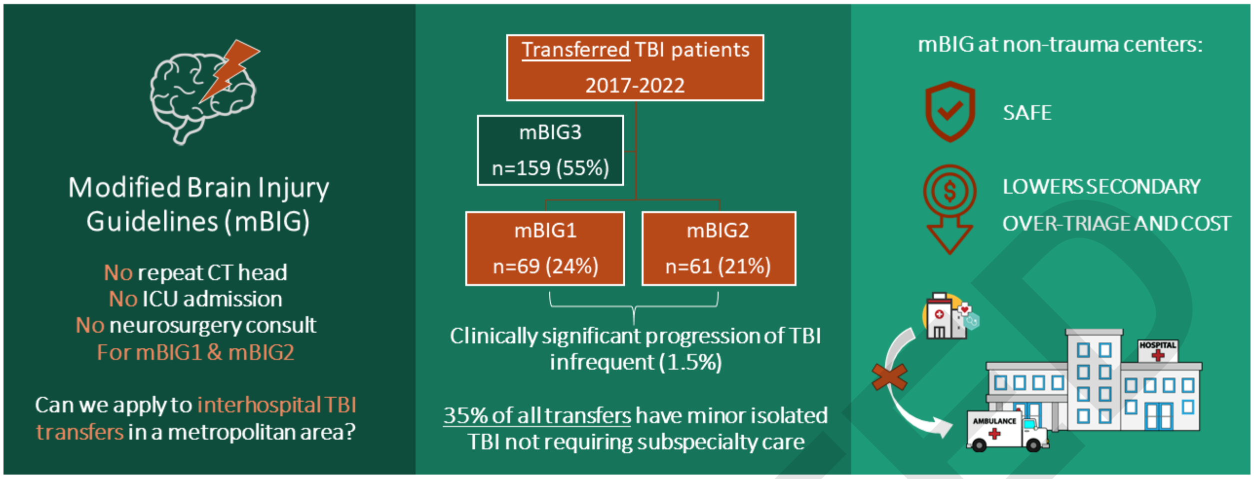

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