

**American College of Radiology
ACR Appropriateness Criteria®
Penetrating Neck Injury**

Variant 1: Penetrating neck injury. Clinical soft injury signs.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|--------|---|----------------------------------|
| CTA neck with IV contrast | 9 | This procedure is the imaging study of choice. See references [2,5,6,8,11-17]. | ☼☼☼ |
| X-ray neck | 7 | Use this procedure to screen and prior to MRI/MRA in gunshot wounds and in some stab wounds if there is any question as to the integrity of the weapon. | ☼☼ |
| US neck | 5 | See references [4,13-15,22,23]. | ○ |
| MRA neck without and with IV contrast | 5 | See references [4,10,13,15,21,26]. | ○ |
| Arteriography neck | 5 | This procedure is usually used as a follow-up test/treatment to a CTA or MRA. See references [2,6,11,20,21]. | ☼☼☼ |
| X-ray biphasic esophagram | 5 | See references [2,6,8,11,27]. | ☼☼☼ |
| MRA neck without IV contrast | 4 | This procedure may be considered in patients with renal insufficiency. | ○ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Variant 2: Penetrating neck injury. Normal or equivocal CTA. Concern for vascular injury.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|--------|---------------------------------|----------------------------------|
| Arteriography neck | 8 | See references [2,6,8,20,21]. | ☼☼☼ |
| MRA neck without and with IV contrast | 5 | See references [4,10,13,15,23]. | ○ |
| MRA neck without IV contrast | 4 | | ○ |
| US neck | 4 | See references [4,13-15,22,23]. | ○ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

Variant 3: Penetrating neck injury. Normal or equivocal CTA. Concern for aerodigestive injury.

| Radiologic Procedure | Rating | Comments | RRL* |
|---|--------|------------------------------------|----------------------------------|
| X-ray single contrast esophagram | 8 | See references [2,6,8,11,27]. | ☼☼☼ |
| MRI neck without and with IV contrast | 5 | See references [4,10,13,15,23,26]. | ○ |
| MRI neck without IV contrast | 5 | | ○ |
| Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate | | | *Relative Radiation Level |

PENETRATING NECK INJURY

Expert Panels on Neurologic and Vascular Imaging: Jason W. Schroeder, MD^{a*}; Thomas Ptak, MD, PhD^b; Amanda S. Corey, MD^c; Osmanuddin Ahmed, MD^d; Walter L. Biffl, MD^e; Joseph A. Brennan, MD^f; Ankur Chandra, MD^g; Michael Ginsburg, MD^h; Michael Hanley, MDⁱ; Christopher H. Hunt, MD^j; Michele M. Johnson, MD^k; Tabassum A. Kennedy, MD^l; Nandini D. Patel, MD^m; Bruno Policeni, MDⁿ; Charles Reitman, MD^o; Michael L. Steigner, MD^p; Shirley I. Stiver, MD, PhD^q; Richard Strax, MD^r; Matthew T. Whitehead, MD^s; Karin E. Dill, MD.^t

Summary of Literature Review

Introduction/Background

In the United States, penetrating neck injuries encompass roughly 1% to 10% of emergency department trauma cases [1,2], with a mortality rate of up to 10% [1,3]. Classically, penetrating neck injuries are described as those injuries that penetrate the platysma muscle and are divided into three anatomic zones: zone I extends from the clavicles and sternal notch to the cricoid cartilage, zone II extends from the cricoid cartilage to the mandibular angle, and zone III extends from the mandibular angle to the skull base [1-4]. Injury to any zone of the neck has the potential to damage multiple densely positioned vital structures because of the associated complex anatomy [4]. Traditionally, penetrating injuries to zone II were immediately taken for surgical exploration, whereas injuries to zones I and III were evaluated by conventional angiography and other modalities, including computed tomographic angiography (CTA) [3,5-7]. However, some current literature supports the use of a “no-zone” approach to the evaluation of penetrating neck injuries [6,7]. Multiple algorithmic approaches are used in evaluation and treatment of these patients [1,2,8,9]. Vascular injury occurs in up to 25% of patients with penetrating neck injuries [2,10], with up to 25% of these vascular injuries being arterial in nature [3].

Current approaches to patients with penetrating neck injuries result from clinical evaluation and the findings of hard versus soft signs. Hard signs of vascular or aerodigestive injury include active hemorrhage, pulsatile or expanding hematoma, bruit or thrill in the region of the wound, hemodynamic instability, unilateral upper-extremity pulse deficit, massive hemoptysis or hematemesis, air bubbling in the wound, and airway compromise. These hard signs of injury are associated with an unstable or a potentially unstable patient and often mandate immediate operative evaluation and treatment without preoperative imaging. Symptoms related to cerebral ischemia are also hard signs of penetrating injury, but these patients may be stable enough to benefit from first performing imaging studies. Imaging of the brain in addition to the head and neck vasculature may be used to determine optimal surgical, endovascular, or medical therapy. Soft signs of vascular and aerodigestive injury include nonpulsatile or nonexpanding hematoma, venous oozing, dysphagia, dysphonia, and subcutaneous emphysema [6,7]. These commonly result in further evaluation, typically with imaging.

Overview of Imaging Modalities

CTA dominates the imaging landscape when it comes to the initial evaluation of patients with penetrating neck trauma who do not require immediate surgical exploration [2,6,8,11]. In early comparisons with catheter angiography, CTA demonstrated high sensitivity and specificity [5,11-16]. This held true in a prospective study in 2012 [5] for detecting vascular and aerodigestive injury by CTA, where sensitivity was 100% and specificity was 97.5%. Early adoption of CTA in the initial evaluation of patients with penetrating injuries to the neck led to a

^aPrincipal Author, Walter Reed National Military Medical Center, Bethesda, Maryland. ^bCo-author, Massachusetts General Hospital, Boston, Massachusetts.

^cPanel Chair (Neurologic), Emory University, Atlanta, Georgia. ^dRush University Medical Center, Chicago, Illinois. ^eJohn A. Burns School of Medicine at the University of Hawaii, Kailua, Hawaii; American Association for the Surgery of Trauma. ^fSan Antonio Military Medical Center, San Antonio, Texas; American Academy of Otolaryngology-Head and Neck Surgery. ^gScripps Green Hospital, La Jolla, California; Society for Vascular Surgery. ^hStanford University School of Medicine, Stanford, California. ⁱPanel Vice-Chair (Vascular), University of Virginia Health System, Charlottesville, Virginia. ^jMayo Clinic, Rochester, Minnesota. ^kUniversity of Texas Medical School, Houston, Texas; neurosurgical consultant. ^lUniversity of Wisconsin Hospital and Clinic, Madison, Wisconsin. ^mFairfax Radiology Consultants PC, Fairfax, Virginia. ⁿPanel Vice-Chair (Neurologic), University of Iowa Hospitals and Clinics, Iowa City, Iowa. ^oMedical University of South Carolina, Charleston, South Carolina; North American Spine Society. ^pBrigham & Women's Hospital, Boston, Massachusetts. ^qSan Francisco, California, neurosurgical consultant. ^rBaylor College of Medicine, Houston, Texas. ^sChildren's National Health System, Washington, District of Columbia. ^tPanel Chair (Vascular), UMass Memorial Medical Center, Worcester, Massachusetts.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

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decrease in overall neck explorations and negative neck explorations as well as the use of catheter angiography and esophagography [17]. A recent retrospective study [18] reviewed the selective nonoperative management of patients with clinical hard signs. Of patients with hard signs who were hemodynamically stable and had a stable airway, 74% who received a CTA were able to avoid surgical neck exploration.

In patients for whom the risk of allergic reaction to iodinated contrast is high or unknown, premedication may be appropriate per ACR recommendations [19]. If there is a high risk for contrast reaction or if iodinated contrast cannot be given, unenhanced computed tomography (CT) imaging of the neck may be performed, but with the understanding the vasculature may be underevaluated.

Catheter angiography has been considered the gold standard for vascular imaging in penetrating neck injury, in particular when zone I or III is involved, although it has been supplanted by CTA. Catheter angiography still has a place when there are equivocal findings on CTA or when a vascular access–based treatment approach is warranted [2,6,8,20,21].

Ultrasound (US) is limited in its use in patients with penetrating neck injury, given the effect of overlying or adjacent soft-tissue injury. It may be complicated by a cervical collar or overlying skin dressings, provides limited evaluation of surrounding structures, and is of limited use in zone I and III injuries [4,13,14,22,23]. Early studies comparing US and catheter-based angiography demonstrated a sensitivity of 91%, a specificity of 98% to 100%, a positive predictive value of 100%, and a negative predictive value of 99% for patients with clinical soft signs imaged by US [24,25].

Magnetic resonance imaging/magnetic resonance angiography (MRI/MRA) are limited in the initial trauma setting given the length of scanning, potentially critical nature of the patient's condition, and concern for metallic foreign bodies [4,13,15,23]. Concern for metallic foreign bodies may be investigated by either CT or radiographs. MRI or MRA use in evaluation of spinal cord injury, traumatic disk injury, ligamentous injury, and blood within the spinal canal, however, is quite valuable [10], as is their application in the evaluation of laryngeal cartilaginous injuries [26].

Fluoroscopic upper gastrointestinal tract examination has its role in the evaluation of penetrating neck injuries but is typically used as a problem-solving modality [2,6,8]. Barium swallow, preferably with water-soluble contrast, may miss significant oropharyngeal and hypopharyngeal injuries, although this imaging examination will typically detect esophageal injuries [27].

As arterial injury occurs in a proportion of patients with penetrating neck injury, one must be cognizant of the possibility of end-organ injury, particularly to the brain. Although not directly related to imaging of the neck in penetrating injuries, imaging of the brain and cerebral vasculature may be considered where cervical vascular injury is determined either by clinical examination, imaging, or surgery.

Discussion of Procedures by Variant

Variant 1: Penetrating neck injury. Clinical soft injury signs.

Radiography

Radiographs are ubiquitous in radiology and in some practices may be employed in the initial evaluation of acute trauma patients [28]. In the initial evaluation in the trauma bay, radiographs of the neck may demonstrate radio-opaque foreign bodies, soft-tissue swelling, airway competency, fractures, and subcutaneous emphysema. With the exception of patients exhibiting clear hard signs necessitating immediate surgical intervention, the initial radiographs are generally followed by a more detailed CT or CTA evaluation.

CTA

After the clinical determination is made regarding the need for immediate surgical exploration (eg, presence of hard versus soft signs), CTA is considered the first-line imaging evaluation, replacing catheter angiography as the preferred modality. Multiple studies have shown CTA to have high sensitivity, in the range of 90% to 100%; specificity ranging from 98.6% to 100%; a positive predictive value of 92.8% to 100%; and a negative predictive value of 98% to 100% [5,12,14] for evaluating vascular injury. In addition to identifying vascular injury, CTA simultaneously identifies extravascular soft-tissue and aerodigestive injuries with a sensitivity of 100% and a specificity ranging from 93.5% to 97.5% [2,5,6,8,12-14,17,29].

CT esophagography has been described for diagnosing suspected upper-digestive-tract injuries in the trauma setting. There are limited data on this imaging modality, which can be performed either in conjunction with the

CTA or as a separate study. In Conradie and Gebremariam's prospective study [30], CT esophagography performed in conjunction with CTA yielded a sensitivity of 100% compared with those evaluated with CT esophagography alone (95%). Specificity varied between 85% and 91% for both studies (CT esophagography alone or in conjunction with CTA).

Arteriography, MRI, MRA, US, and Esophagram

Although catheter angiography, MRI, MRA, US, and fluoroscopic studies could be used in the initial evaluation of penetrating neck injury, these are typically relegated to problem solving for specific issues in contemporary trauma workups.

Variant 2: Penetrating neck injury. Normal or equivocal CTA. Concern for vascular injury.

Arteriography

Catheter angiography was traditionally used in the evaluation of zones I and III but now is considered primarily in the evaluation of patients with a normal or equivocal CTA with a concerning penetrating foreign body trajectory [6,8] or when endovascular therapy is to be performed [1]. Catheter angiography may be performed in follow-up to equivocal CTA examinations, especially when a clinically significant vascular injury cannot be reliably excluded. A limitation of CTA is the potential for streak artifact from retained metallic foreign bodies; in this instance, digital subtraction catheter angiography may be more sensitive and appropriate for vascular evaluation [20,21].

US

Studies in the 1990s demonstrated a high sensitivity and specificity, as well as positive and negative predictive values, of US in patients with penetrating injuries to the neck [24,25,31]. In considering the strengths of US evaluation versus the limitations as discussed, in only very specific circumstances may US provide additional diagnostic insight. For overall structural and functional assessment in the initial evaluation period, arteriography remains the preferred modality.

MRA

MRA may be feasible in the clinically stable patient for the evaluation of vascular injuries, although limitations such as potential retained foreign bodies and length of the examination may preclude its use [4,13,15,23]. In select and appropriate patients, MRI techniques, including 2-D and 3-D time-of-flight, contrast-enhanced time-resolved, and phase-contrast techniques, are available to evaluate the neck vasculature [32]. The 2-D and 3-D time-of-flight techniques do not require contrast for their technique.

Variant 3: Penetrating neck injury. Normal or equivocal CTA. Concern for aerodigestive injury.

Barium Swallow

Various algorithms are present in practice for the use of esophagrams in the evaluation of aerodigestive injury in the patient with penetrating neck injury. These algorithms vary depending on factors such as whether or not the patient is symptomatic, the degree of clinical concern, the outcome of the initial CT or CTA, and the mechanism of injury [2,6,8,11]. Ahmed et al [27] argue that contrast fluoroscopic studies should not be used in the evaluation of oropharyngeal and hypopharyngeal injuries given that water-soluble and thin barium examinations missed 13 of 13 injuries in this area, compared with video endoscopy performed at the bedside. Water-soluble contrast is preferred, because there is the risk of extraluminal contrast extravasation. Panendoscopy with laryngoscopy, bronchoscopy, and esophagoscopy (flexible and rigid) is the gold standard to rule out oropharyngeal, hypopharyngeal, laryngotracheal, and esophageal injuries.

MRI

Overall, CT or CTA is preferred when evaluating for acute osseous and soft-tissue cervical injuries. MRI, in particular fat-suppressed T2-weighted imaging, is more sensitive for assessing potential cartilaginous and fibrous injuries but is relegated to specific problem-solving cases and is not routinely performed [26]. Standard MRI sequences to include short tau inversion recovery and T2, as well as gadolinium-enhanced T1 with fat saturation, may help further define the extent of injury of the soft tissues.

Summary of Recommendations

- In patients with penetrating neck injuries with clinical soft injury signs and in patients with hard signs of injury who do not require immediate surgical exploration, CTA of the neck is the preferred imaging procedure to evaluate the extent of injury.

- When there remains clinical concern for vascular injury despite a normal or equivocal CTA of the neck, catheter-based arteriography is useful for further evaluation. The benefit of arteriography is the ability to perform, in tandem, an endovascular procedure if needed.
- If there remains a concern for aerodigestive injury despite a normal or equivocal CTA of the neck, an x-ray single contrast esophagram may be considered, but it should be used in conjunction with direct visualization techniques.

Summary of Evidence

Of the 33 references cited in the *ACR Appropriateness Criteria® Penetrating Neck Injury* document, 6 are categorized as therapeutic references. Additionally, 27 references are categorized as diagnostic references including 1 well-designed study, 2 good-quality studies, and 8 quality studies that may have design limitations. There are 22 references that may not be useful as primary evidence.

The 33 references cited in the *ACR Appropriateness Criteria® Penetrating Neck Injury* document were published from 1995 to 2017.

Although there are references that report on studies with design limitations, 3 well-designed or good-quality studies provide good evidence.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the *ACR Appropriateness Criteria® Radiation Dose Assessment Introduction* document [33].

| Relative Radiation Level Designations | | |
|---------------------------------------|-------------------------------------|---|
| Relative Radiation Level* | Adult Effective Dose Estimate Range | Pediatric Effective Dose Estimate Range |
| ○ | 0 mSv | 0 mSv |
| ⊕ | <0.1 mSv | <0.03 mSv |
| ⊕⊕ | 0.1-1 mSv | 0.03-0.3 mSv |
| ⊕⊕⊕ | 1-10 mSv | 0.3-3 mSv |
| ⊕⊕⊕⊕ | 10-30 mSv | 3-10 mSv |
| ⊕⊕⊕⊕⊕ | 30-100 mSv | 10-30 mSv |

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as “Varies”.

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

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The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.