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American College of Radiology
ACR Appropriateness Criteria®

Penetrating Neck Injury

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

Procedure	Appropriateness Category	Relative Radiation Level
Radiography neck	Usually Appropriate	☢☢
CTA neck with IV contrast	Usually Appropriate	☢☢☢
US neck	May Be Appropriate	O
Arteriography neck	May Be Appropriate	☢☢☢
Fluoroscopy biphasic esophagram	May Be Appropriate	☢☢☢
MRA neck without and with IV contrast	May Be Appropriate	O
MRA neck without IV contrast	May Be Appropriate	O

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

Procedure	Appropriateness Category	Relative Radiation Level
Arteriography neck	Usually Appropriate	☢☢☢
US neck	May Be Appropriate	O
MRA neck without and with IV contrast	May Be Appropriate	O
MRA neck without IV contrast	May Be Appropriate	O

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

Procedure	Appropriateness Category	Relative Radiation Level
Fluoroscopy single-contrast esophagram	Usually Appropriate	☢☢☢
MRI neck without and with IV contrast	May Be Appropriate	O
MRI neck without IV contrast	May Be Appropriate	O

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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 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.

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A. 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.

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

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

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A. 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].

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

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

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injury.

A. 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.

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

B. 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.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	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 (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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Disclaimer

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.

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