REVIEW

Imaging of Penetrating Injuries of the Head and Neck: Current Practice at a Level I Trauma Center in the United States

Naoko Saito,[1*] Rania Hito,[1] Peter A. Burke[3] and Osamu Sakai[1,2]**

Departments of [1]Radiology and [2]Otolaryngology − Head and Neck Surgery, and [3]Division of Acute Care & Trauma Surgery/Surgical Critical Care, Boston Medical Center, Boston University School of Medicine, Massachuesetts, USA

(Received for publication on October 9, 2013)
(Revised for publication on January 10, 2014)
(Accepted for publication on March 17, 2014)
(Published online in advance on June 10, 2014)

Penetrating neck injuries are commonly related to stab wounds and gunshot wounds in the United States. The injuries are classified by penetration site in terms of the three anatomical zones of the neck. Based on this zonal classification system, penetrating injuries to the head and neck have traditionally been evaluated by conventional angiography and/or surgical exploration. In recent years, multidetector-row computed tomography (CT) angiography has significantly improved detectability of vascular injuries and extravascular injuries in the setting of penetrating injuries. CT angiography is a fast and minimally invasive imaging modality to evaluate penetrating injuries of the head and neck for stable patients. The spectrum of penetrating neck injuries includes vascular injury (extravasation, pseudoaneurysm, dissection, occlusion, and arteriovenous fistula), aerodigestive injury (esophageal and tracheal injuries), salivary gland injury, neurologic injury (spinal canal and cerebral injuries), and osseous injury, all of which can be evaluated using CT angiography. Familiarity with the complications and imaging characteristics of penetrating injuries of the head and neck is essential for accurate diagnosis and optimal treatment. (doi: 10.2302/kjm.2013-0009-RE; Keio J Med 63 (2) : 23–33, June 2014)

***Keywords*: penetrating injury, head and neck, CT angiography, vascular injury, aerodigestive injury**

Introduction

Penetrating trauma to the head and neck accounts for 5–10% of all trauma cases that present to emergency departments in the United States.[1] Significant penetrating neck injury violates the platysma by definition. Most commonly these injuries are secondary to stab wounds or gunshot wounds (**Fig. 1**) in the United States, whereas penetrating neck injuries are rare in Japan and the most common causes of such injuries in Japan are self-harm and stab wounds from accidents. Boston Medical Center is the largest and busiest provider of trauma and emergency services in the Greater Boston area with over 130,000 emergency encounters each year. The trauma service treats and evaluates 3,000 and admits over 2,000 injured patients annually. We see approximately 80% blunt injuries and 20% penetrating injuries, and these are broken down evenly between gunshot and stab wounds.

The mortality rates for penetrating neck injuries can be as high as 10%.[1] Therefore, these injuries require immediate medical attention by surgeons and radiologists. The imaging modalities for penetrating neck injury patients are radiography, endoscopy, ultrasound, computed tomography (CT), and magnetic resonance imaging

Current addresses: *Department of Radiology, Saitama International Medical Center, Saitama Medical University, Saitama, Japan (NS) and **Department of Radiology, Massachusetts General Hospital, Harvard Medical School, Massachuesetts, USA (RH)
Reprint requests to:Osamu Sakai, MD, PhD, Department of Radiology and Otolaryngology − Head and Neck Surgery,
Boston Medical Center, Boston University School of Medicine, FGH Building, 3rd Floor, 820 Harrison Avenue, Boston, MA 02118, USA
E-mail: osamu.sakai@bmc.org

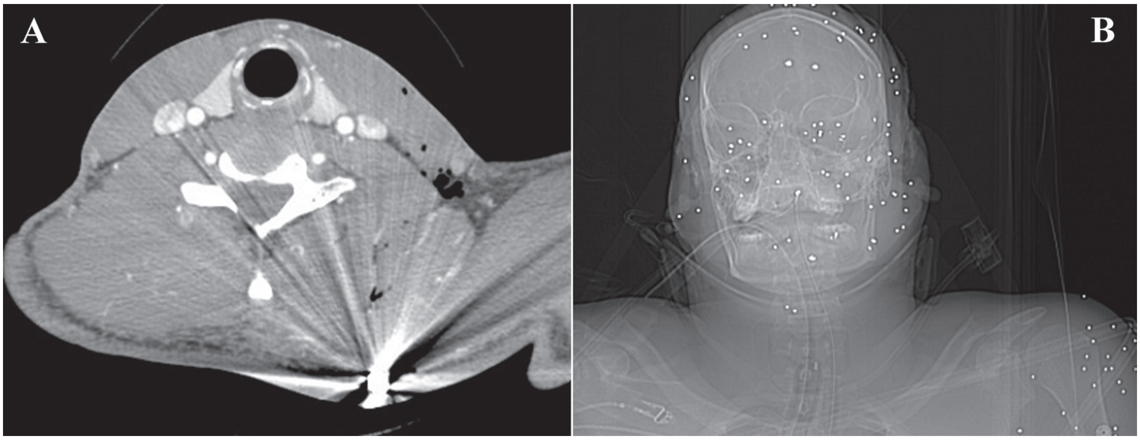

Fig. 1 Gunshot injury.
(A) Axial CTA image shows a large bullet fragment resulting in a metallic artifact. (B) Scout image from CTA demonstrates multiple gunshot fragments in the head, neck, and left shoulder.

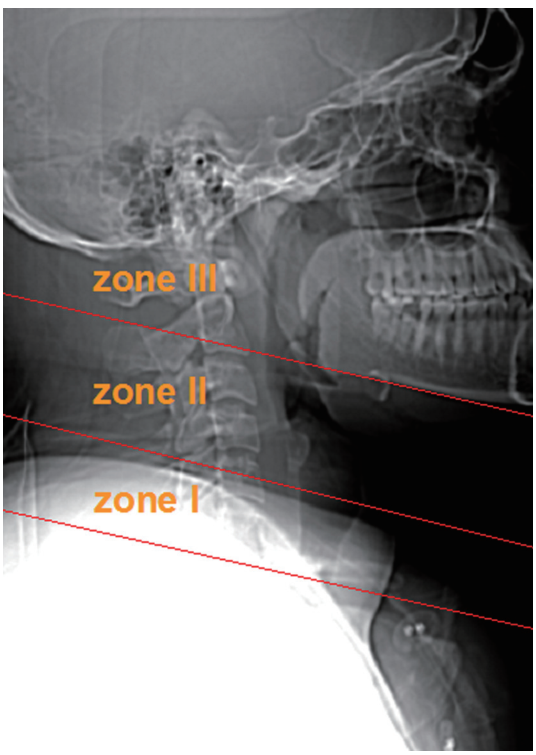

Fig. 2 Zones of the neck.
Lateral neck radiograph shows the three anatomical zones of the neck. Zone I extends from the clavicles to the inferior border of the cricoid cartilage. Zone II extends from the inferior border of the cricoid cartilage to the angle of the mandible. Zone III extends from the angle of the mandible to the skull base.

(MRI). Of these, CT angiography (CTA) is increasingly used in the workup of penetrating injury patients without indications for immediate surgical exploration. CTA can delineate vascular injury, which is seen in up to 25% of penetrating wounds.[1–3] CT and CTA can also reveal non-vascular injuries and the trajectory of the wound.

The aims of this article are to review common penetrating injuries to the head and neck, the anatomic classification of the neck zone, and CTA findings of vascular/extravascular injuries and to describe the traditional diagnostic algorithm and the impact of CTA on the diagnostic algorithm and injury management.

Definition of Penetrating Injury of the Head and Neck

By definition, a penetrating neck injury violates the full thickness of the platysma: if the platysma is intact, the wound is considered superficial. Penetrating neck injuries are classified by penetration site into the three anatomical zones of the neck (**Fig. 2**) as described by Monson et al.[4] and Roon et al.[5]

Zone I extends from the clavicles to the inferior border of the cricoid cartilage. Important structures in zone I include segments of the innominate artery and brachiocephalic veins, segments of the subclavian arteries and veins, the common carotid and vertebral arteries, esophagus, trachea, and thyroid.

Zone II extends from the inferior border of the cricoid cartilage to the angle of the mandible. It is the most common area affected by penetrating injuries. Important structures in zone II include the common, internal, and external carotid arteries and jugular veins, larynx, upper esophagus, and pharynx.

Zone III extends from the angle of the mandible to the skull base. Important structures in zone III include the internal carotid and vertebral arteries, external carotid artery branches, internal jugular vein, and pharynx.

Imaging Techniques and Practical Tips for Assessing Penetrating Injury of the Head and Neck

CTA is increasingly used in the workup of patients with penetrating injury who do not require immediate surgical exploration.[6–12] At most institutions, CTA has replaced angiography as the initial method of diagnosis in patients with penetrating head and neck injuries. At Boston Medical Center, CTA is performed using a 64-multidetector-row CT scanner with a 0.625-mm configuration from the aortic arch to the skull base for neck CTA or to the vertex of the skull for head and neck CTA. The patient is injected intravenously with 100 mL of iodinated contrast material (350–370 mgI/ml) at 5 mL/s through an 18-gauge catheter located in an antecubital fossa vein. Right-sided injection is preferred to improve the bolus of contrast agent by limiting venous regurgitation from compression of the brachiocephalic vein by the aortic arch. We use an automated triggering device with a region of interest placed in the carotid bifurcation. Scanning parameters common to the examinations are tube potential of 120 kVp and a use of automatic exposure control systems (max 660 mA). Axial, sagittal, and coronal multiplanar reformation (MPR) and maximum intensity projection (MIP) reformats with 5-mm slice thickness at 2-mm intervals are generated. Additional three-dimensional (3D) reconstructions with volume renderings are performed in a 3D Lab or by attending radiologists at independent workstations.

It has been shown that utilization of CTA decreases the need for surgical exploration.[11] Some studies have shown 100% sensitivity in detecting arterial lesions using direct signs and indirect signs.[1,2,13] The direct signs are wall irregularity, contrast extravasation, lack of vascular enhancement, and caliber changes; the indirect signs are bone and bullet fragments less than 5 mm from a major vessel or in the path of injury through a vessel and hematoma in the carotid sheath.[13]

CTA has many advantages over conventional catheter angiography. CTA is a rapid, non-invasive, and relatively inexpensive modality. CTA also reveals the trajectory of the wound track and non-vascular injuries. Determination of the trajectory is important because the organs lying along the wound track have a high likelihood of injury.[2] However, there are some limitations of CTA. Streak artifact from shoulders, retained metallic fragments, and dental fillings can prevent adequate visualization of vessels (**Fig. 3**). Also, suboptimal timing of contrast or failed intravenous injection may lead to decreased opacification of vessels, which can impair the detection of vascular injury (**Fig. 4**).

Other imaging modalities for evaluating penetrating injuries include ultrasound and MRI.[2,14] Ultrasound is a quick, non-invasive, and readily available tool; however, the technique is highly operator-dependent, and air from the injury, artifacts from retained metallic fragments, and hematoma can limit evaluation of vital structures. MRI provides superior soft tissue contrast and is performed in patients with suspected spinal injury, cerebral injury, or soft tissue injuries including those of the salivary glands. MR angiography has also been proposed in the evaluation of vascular injury.[15] Although MRI has many advantages, it is unlikely to become a first-line imaging modality in the emergency setting because it is time consuming and also because metallic foreign bodies can preclude the patient from safely entering the MRI suite.

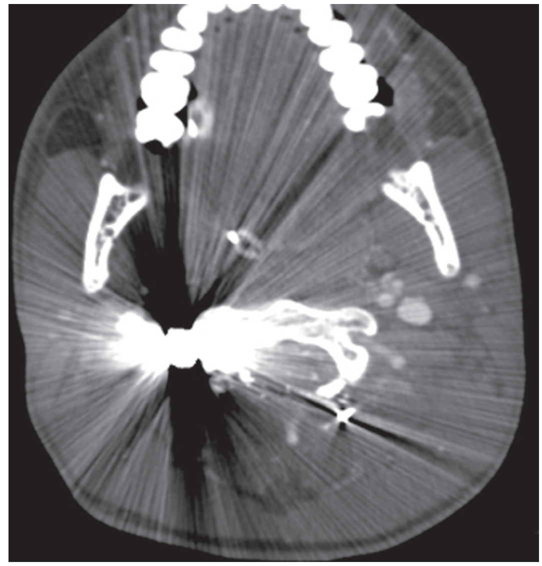

Fig. 3 Limitations of CTA: streak artifact.
Axial CTA image demonstrates a streak artifact from a bullet fragment obscuring the adjacent right vertebral artery.

Management of Penetrating Head and Neck Injuries

Surgical access to zone I and zone III injuries is challenging because of the inherent difficulties in accessing the thoracic or intracranial cavity. Zone II, on the other hand, is readily surgically accessible. Traditionally, in the evaluation of hemodynamically stable patients with penetrating neck trauma, patients with zone I and zone III injuries were evaluated with conventional angiography, whereas zone II patients were explored surgically.[1–3,14,16] Patients with hemodynamic instability who present with clinically detectable signs of injury such as expanding hematomas, active hemorrhage, neurologic symptoms, bruit, thrill, hematemesis, hemoptysis, stridor, or air leak undergo immediate surgical exploration.[3,14,16]

In recent years, with evolution of CT, CTA has become increasingly used for the initial evaluation of penetrating

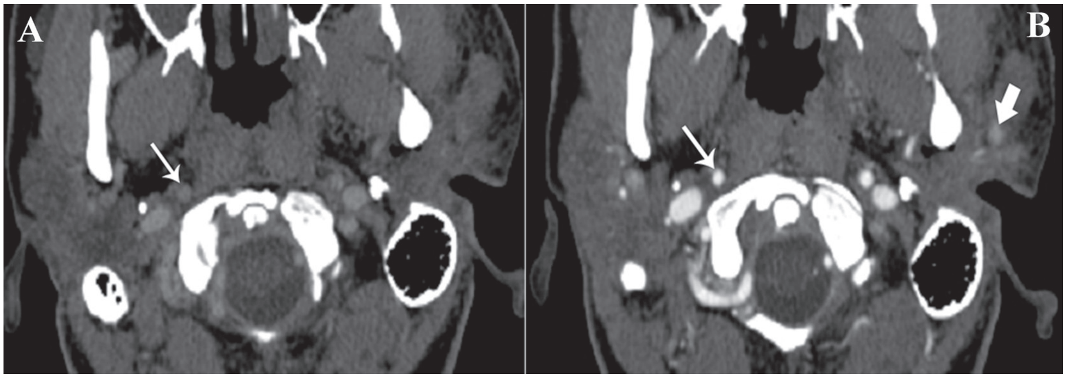

Fig. 4 Limitations of CTA: suboptimal timing of contrast.
(A) Axial CTA image demonstrates suboptimal opacification of the arteries (thin arrow) secondary to poor timing of the contrast bolus. (B) Repeat CTA exam shows adequate opacification of the vessels (thin arrow). Extravasation in the pre-auricular soft tissues is now visualized (thick arrow).

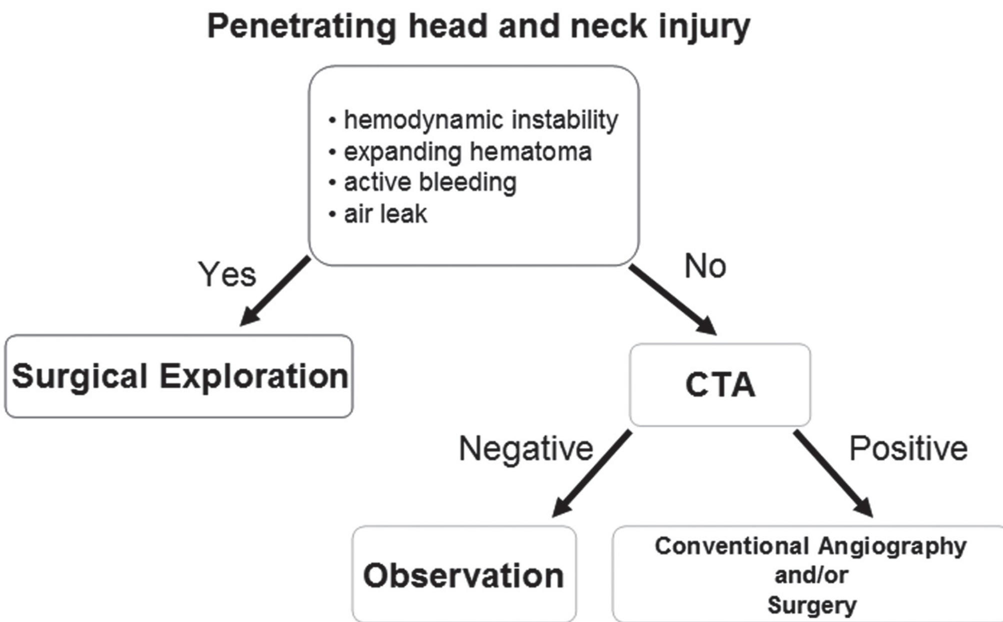

Fig. 5 Recent recommendations from the literature for the management of penetrating head and neck injuries.

neck injuries in all zones; this approach allows for highly selective surgical interventions and decreases the need for surgical exploration.[6–12,14] Recent recommendations in the literature for the management of penetrating neck injury are summarized in **Fig. 5**. [1–3,6–12,14,16,17] Our current diagnostic and management algorithm of penetrating neck injury at Boston Medical Center is summarized in **Fig. 6**.

Imaging of Penetrating Head and Neck Injuries

Vascular injury

Arterial injuries are seen in about 25% of patients with penetrating neck injuries.[1–3] Carotid artery injuries are seen in 80% of vascular injuries, and vertebral artery injuries are seen in 43%.[18,19] Approximately 20% of vascular injuries involve venous structures.[3] Venous injuries are more commonly clinically silent when compared with arterial injuries, and injuries of peripheral branches of the cervical veins are often treated conservatively. Therefore,

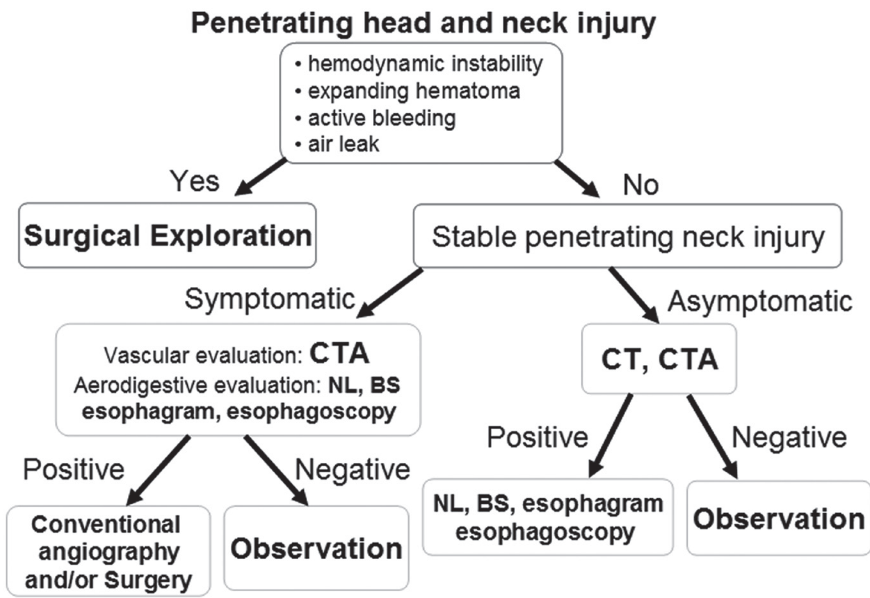

Fig. 6 The diagnostic and management algorithm for penetrating head and neck injuries at Boston Medical Center.
CTA, CT angiography; NL, nasolaryngoscopy; BS, barium swallow.

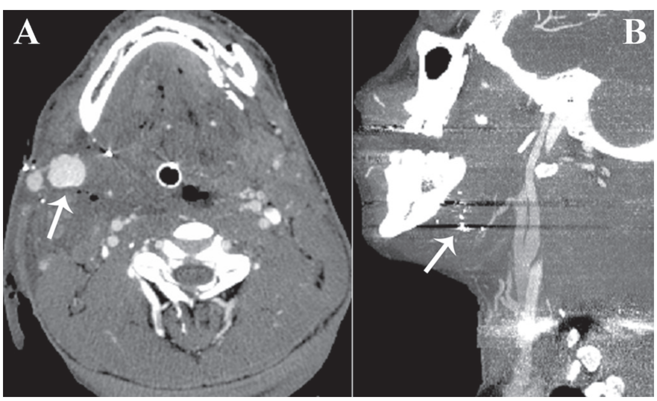

Fig. 7 Vascular injury: extravasation.
Arterial extravasation with zone II gunshot injury. (A) Axial CTA image shows a focal region of extravasated contrast (arrow) inferior to the right mandible likely from the right facial artery. (B) Sagittal MIP image demonstrates bullet fragments (arrow) in the region of the right facial artery, likely the source of extravasation.

imaging should be focused on the identification of more clinically significant injuries. The optimal imaging strategy for diagnosis of cervical venous injuries has not yet been determined; however, CTA has been shown to demonstrate these injuries well.[2] Vascular injuries seen on CTA include extravasation, pseudoaneurysm, dissection, occlusion, and arteriovenous (AV) fistula.[1–3]

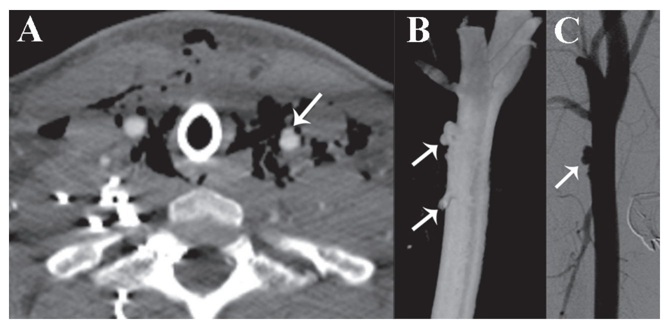

Fig. 8 Vascular injury: pseudoaneurysm.
Pseudoaneurysm with zone I gunshot injury. (A) Axial CTA image demonstrates small outpouching (arrow) at the proximal left common carotid artery, confirmed on conventional angiography (B: 3D, C: lateral projection) where multiple pseudoaneurysms (arrows) are visualized. A stent was placed in the left common carotid artery.

Extravasation

CTA demonstrates extravasation (**Fig. 7**) as contrast pooling outside the vascular lumen.[2] Proximity to known vasculature can help identify the injured vessel. Lack of vascular enhancement in the parent vessel can also be seen in the setting of extravasation.

Pseudoaneurysm

Pseudoaneurysm formation (**Fig. 8**) results from partial or complete disruption of the vessel wall. It is a relatively common type of vascular injury and accounts for 33%

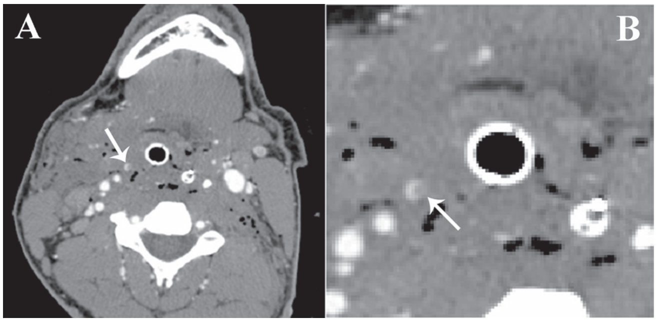

Fig. 9 Vascular injury: dissection.
Arterial dissection with zone II gunshot injury. (A and B) Axial CTA images (B: magnified image) demonstrate a filling defect in the right lingual artery secondary to dissection (arrow).

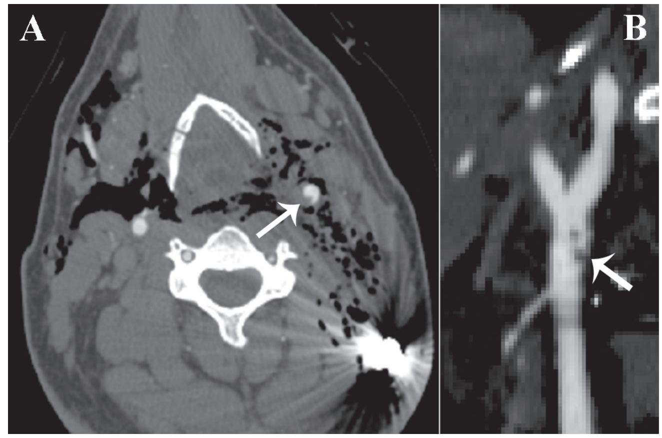

Fig. 10 Vascular injury: dissection.
Arterial dissection with zone II gunshot injury. Axial (A) and sagittal (B) CTA images demonstrate a filling defect and intimal flap (arrow) in the left distal common carotid artery.

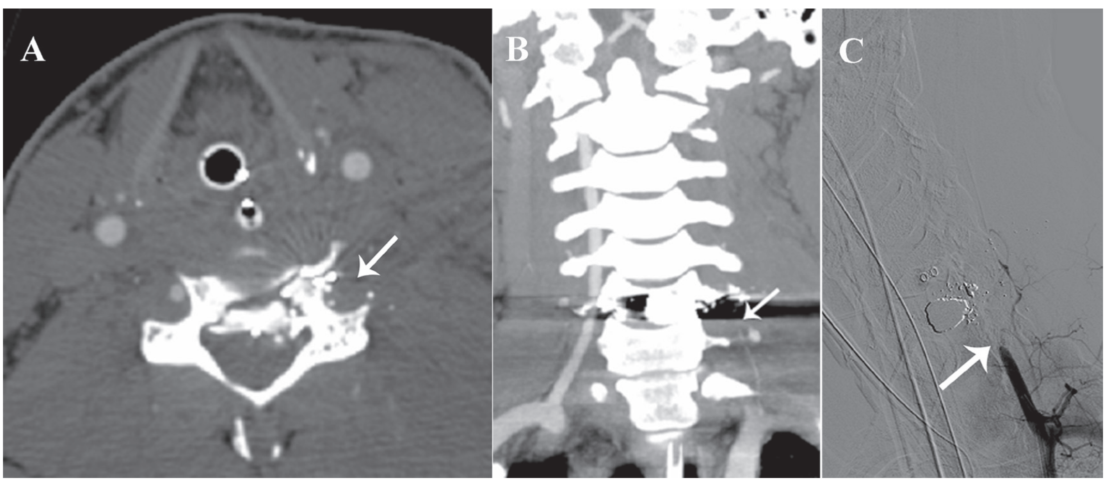

Fig. 11 Vascular injury: occlusion.
Occlusion with zone II gunshot wound. Axial (A) and coronal (B) CTA images demonstrate lack of opacification of the left vertebral artery (arrows) from its origin with retained bullet in vertebral body of C6. (C) Conventional angiogram confirmed the occlusion (arrow) of the left vertebral artery at C7 level with patency of its origin.

of internal carotid artery lesions after penetrating trauma.[18,20] CTA shows an outpouching of contrast from the lumen with widening of the vessel contour.[2,6–12,20] Treatment consists of ligation, embolization, or bypass surgery. Occasionally conservative management is utilized.

Dissection

Dissection (**Figs. 9** and **10**) is rare in penetrating trauma, affecting less than 2% of patients.[20] CTA demonstrates an enlarged vessel diameter with narrowed eccentric lumen secondary to an intramural hematoma. Non-occlusive dissection can appear as focal intraluminal filling defects.[2,6–12,20] Conservative treatment consists of anticoagulation; however, in the setting of other injuries such as hematoma and solid organ lacerations, heparin may be contraindicated. Aspirin is used in this setting at Boston Medical Center. Endarterectomy, bypass, interposition graft, and ligation are surgical options.

Occlusion

Partial or complete occlusion (**Fig. 11**) is the most common type of vascular injury in penetrating trauma.[20] CTA reveals the absence of vascular enhancement. Proximal dissection may or may not be present.[2,6–12,20] Treatment consists of anticoagulation or revascularization.

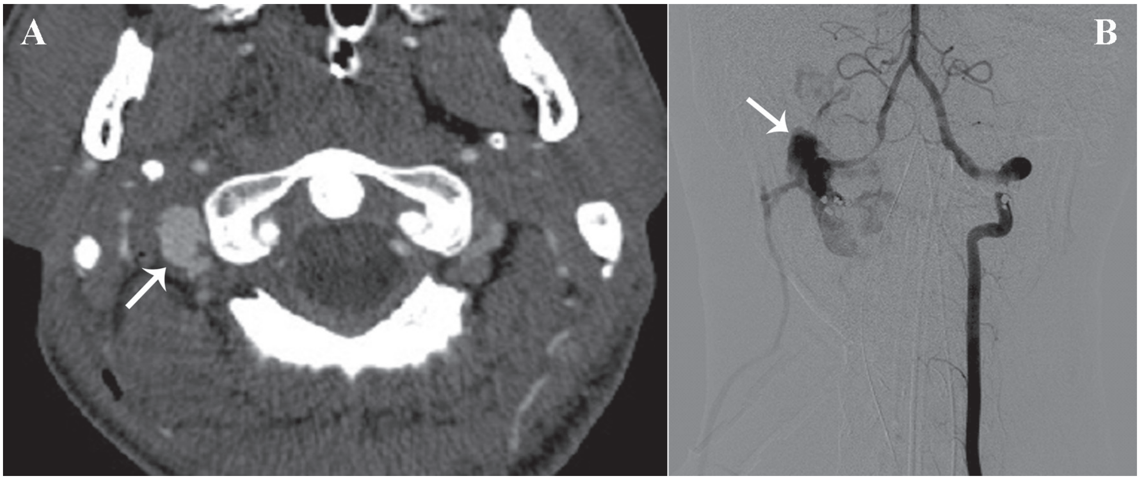

Fig. 12 Vascular injury: AV fistula.
AV fistula with zone III gunshot injury. (A) Axial CTA image demonstrates pooling of contrast (arrow) at the C1 level, which could indicate a pseudoaneurysm. (B) Conventional angiogram shows rupture of the right vertebral artery at the C1 level, with rapid filling of a high right cervical venous pouch (arrow) and a draining vein. The AV fistula was successfully embolized.

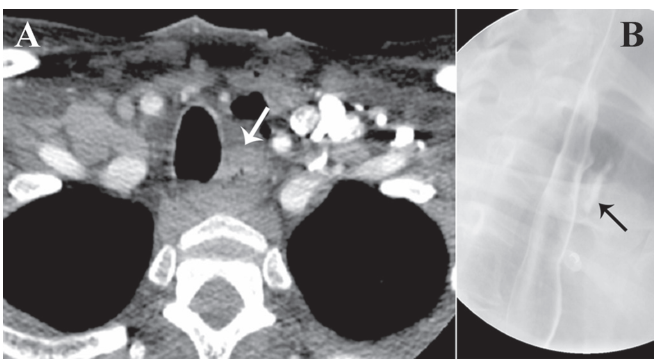

Fig. 13 Esophageal injury.
Esophageal injury with zone I gunshot injury. (A) Axial CTA image demonstrates hematoma (arrow) anterior to the esophagus as well as thickening of the esophagus. (B) Barium swallow confirms esophageal tear (arrow) anteriorly at the level of the clavicles. Surgical repair was performed successfully.

AV fistula

Patients with a bruit typically undergo conventional angiography because the likelihood of an AV fistula is high and conventional angiography allows the opportunity of treatment. Direct communication can be demonstrated on CTA with the enhancement of venous structures being equal to that of the arteries[2,6–12,20] (**Fig. 12**). Treatment is typically surgical; however, embolization can be performed.

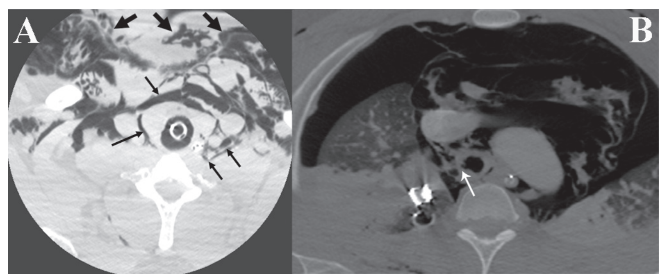

Fig. 14 Tracheal injury.
Tracheal injury with zone I gunshot injury. (A) Axial CTA image in lung window shows massive pneumomediastinum (thin arrows) and subcutaneous air (thick arrows). (B) Chest CT demonstrates irregularity at the right lateral trachea (arrow), which was confirmed surgically and successfully repaired.

Aerodigestive injury

Esophageal injury

Traumatic injury to the esophagus is rare, being seen in 0.9–6.6% of penetrating neck injuries.[2] It has been shown that a delay in diagnosis and surgical intervention increases the number of complications resulting from mediastinitis, abscess, and sepsis.[21] Early detection of esophageal injuries is imperative as mortality is estimated to be up to 20%.[2,21,22]

CT findings of esophageal injury (**Fig. 13**) include esophageal wall thickening, periesophageal gas and fluid collection, mediastinal fluid collection, mediastinal inflammation, and focal esophageal wall defect.[2,23] MPR images provide a better appreciation of the extent

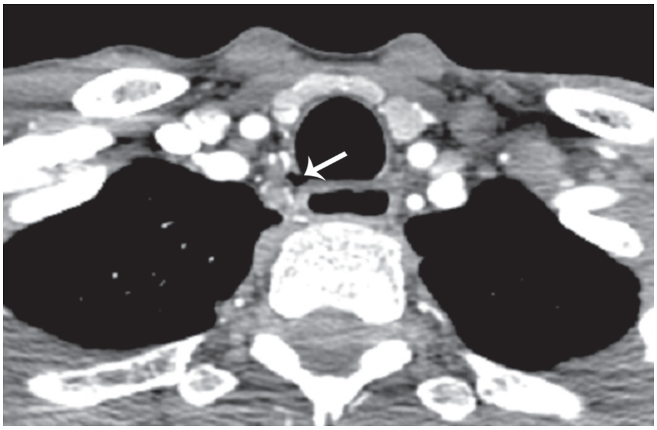

Fig. 15 Tracheal diverticulum.
Axial CTA image shows outpouching of air at the posterolateral trachea that indicates a tracheal diverticulum (arrow), not a tracheal injury. This is the typical location for a tracheal diverticulum.

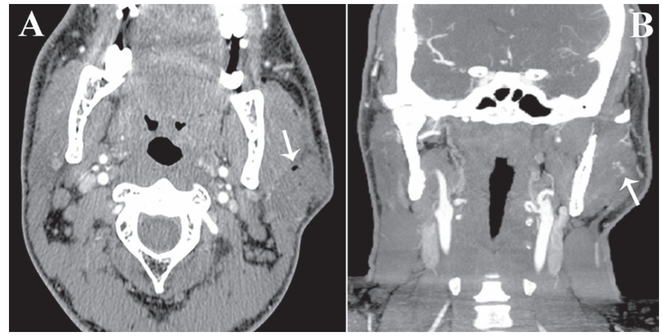

Fig. 16 Salivary gland injury.
Parotid gland injury with zone III stab wound. (A) Axial CTA image demonstrates left parotid gland hematoma with small focus of air (arrow) adjacent to the wound. (B) Coronal MIP image demonstrates small foci of extravasation (arrow) at the superior aspect of the left parotid gland.

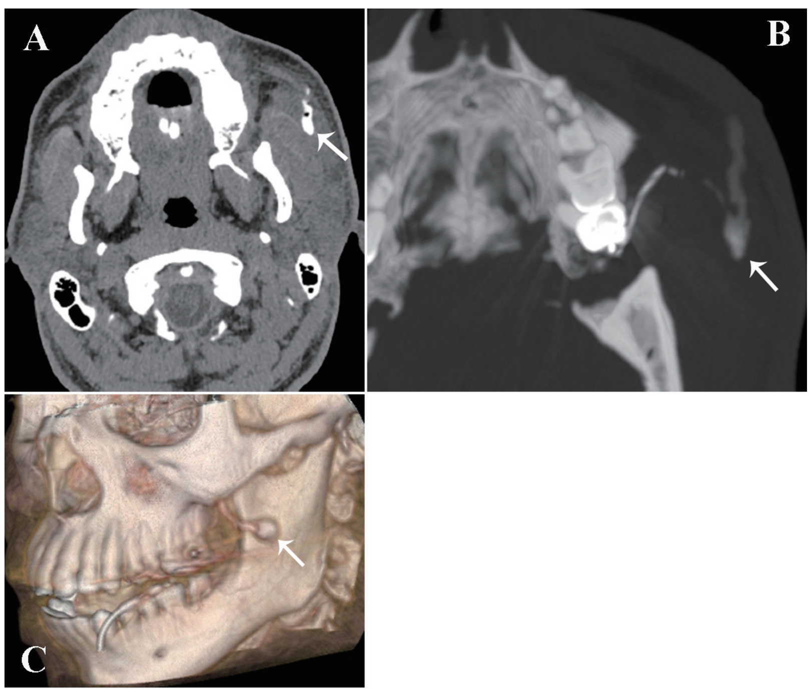

Fig. 17 Salivary gland injury.
Parotid gland injury with zone III stab wound. CT sialogram (A: axial, B: axial MIP, C: 3D) demonstrates parotid duct injury and contrast leakage through the fistula (arrows).

of esophageal injuries and the relation to adjacent structures.[23] If esophageal injury is suspected, fluoroscopic esophagography and endoscopy are indicated.

Tracheal injury

Tracheal injuries are uncommon in penetrating neck injury, occurring in 1–7% of patients.[2,21] If a wound track crosses the trachea or larynx, tracheal injury must be considered. CT reveals a focal defect or contour deformity of the tracheal wall, which are direct signs of tra-

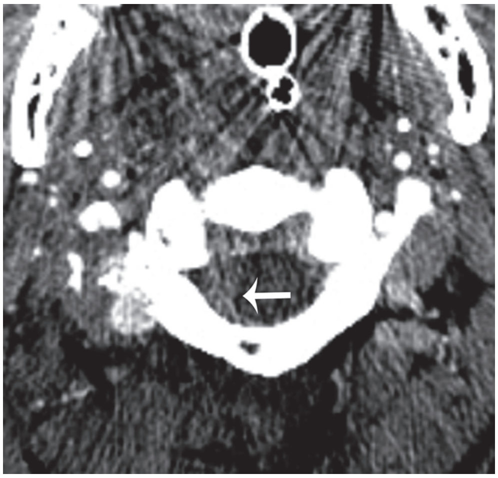

Fig. 18 Epidural hematoma in spinal canal.
Epidural hematoma with gunshot wound. CTA axial image demonstrates a high-density epidural hematoma (arrow) at the right lateral spinal canal deforming the thecal sac.

cheal injury (**Fig. 14**). Other findings of tracheal injury are paratracheal air, pneumomediastinum, and soft tissue emphysema in the neck.[2,21] Using MPR images with lung and soft tissue window settings is helpful to detect direct and indirect signs of tracheal injury on CT.[24] It should be kept in mind that a tracheal diverticulum[25] (**Fig. 15**) may be mistaken for tracheal injury in the trauma setting; however, knowing the common location of tracheal diverticula at the right posterolateral tracheal wall can assist in differentiating the two diagnoses.

Salivary gland injury

Salivary gland injury is a soft tissue injury of the neck, and salivary glandular damage (**Figs. 16** and **17**) can occur in penetrating neck trauma. Injury of Stenson's and Warthin's ducts can result in post-traumatic sialoceles and fistulas that may require surgery. Facial nerve injury may occur in cases of parotid gland injury.

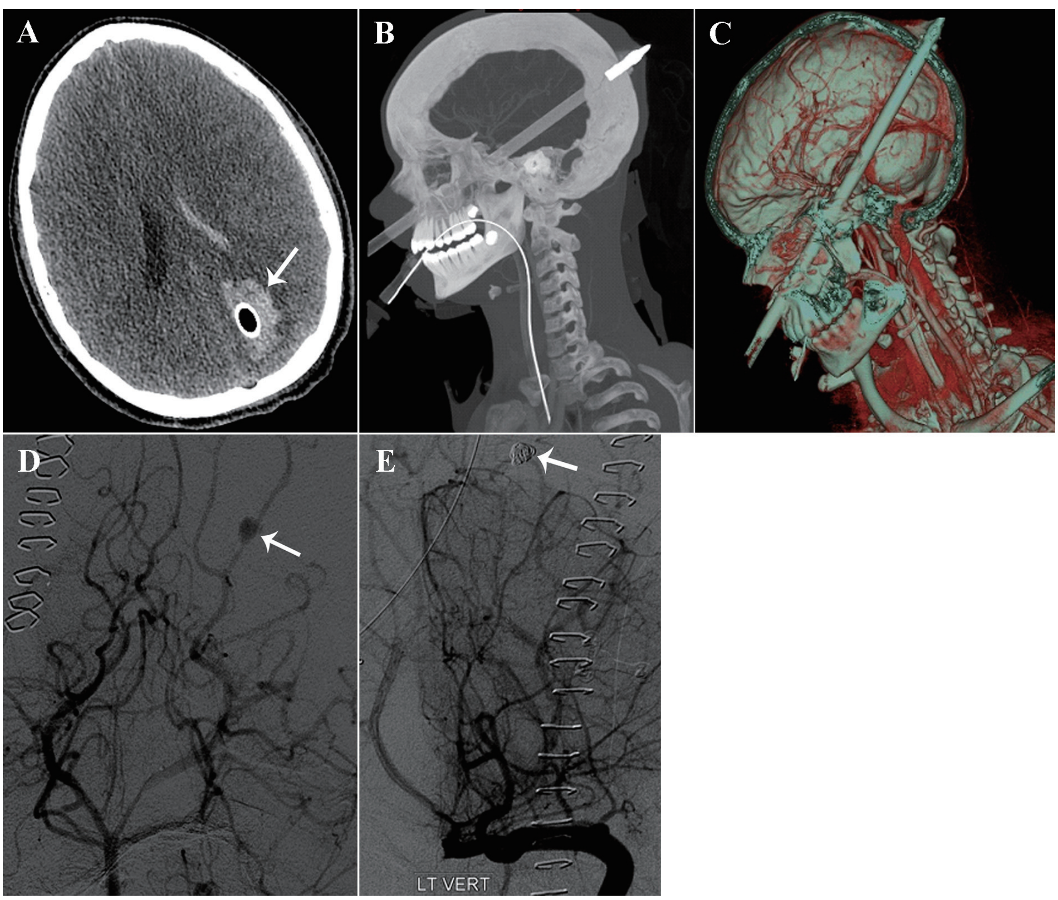

Fig. 19 Cerebral injury.
Cerebral injury caused by an arrow. (A) Axial unenhanced CT demonstrates parenchymal hemorrhage (arrow) around the arrow in the left parietal lobe. CTA images (B: sagittal MIP, C: 3D VR (volume rendering)) demonstrate an arrow entering the nasal cavity and exiting posteriorly through the parietal skull. (D) Conventional angiogram demonstrates a left distal posterior cerebral artery pseudoaneurysm (arrow) after removal of the projectile. (E) The pseudoaneurysm was successfully coiled (arrow).

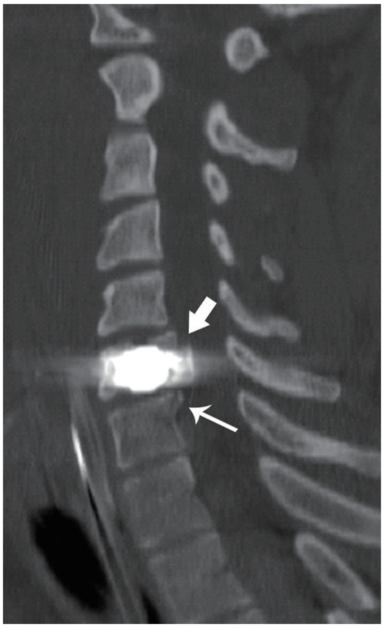

Fig. 20 Spinal fracture.
Spinal fracture with gunshot wound. Sagittal CT image in bone window demonstrates a bullet fragment within the vertebral body of C6, as well as fractures of the C6 body with posterior displacement (thick arrow), and a small minimally displaced fracture at the vertebral superior endplate of C7 (thin arrow).

Neurogenic injury

Injury to the central nervous systems including spinal cord injury (**Fig. 18**) and cerebral injury (**Fig. 19**) can occur with penetrating trauma to the head and neck. Approximately 11–14% of spinal cord injuries are penetrating injuries to the cervical spine.[2,13] Spinal cord injury is implied when a wound track extends through the canal. Gas, bone fragments, or foreign bodies in the spinal canal signify dural violation. MRI can be performed to confirm or further investigate neurogenic injury if there is no metallic foreign body present that precludes MRI.

Osseous injury

Fractures of the skull, facial bone, and cervical spine (**Fig. 20**) may be present in penetrating injuries to the head and neck. Temporal bone fracture (**Fig. 21**) is frequently associated with various complications such as nerve injury, ossicular chain injury, vascular injury, and cerebral injury.

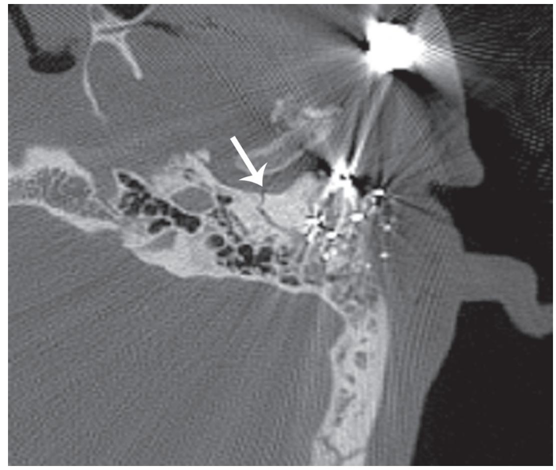

Fig. 21 Temporal bone fracture.
Temporal bone fracture (arrow) resulting from gunshot wound. The fracture extends to the glenoid fossa and is demonstrated with multiple retained bullet fragments.

Unstable cervical spine injuries are rare after penetrating trauma to the head and neck; however, thorough investigation of the cervical spine is needed. Cervical collars are not recommended in this setting as other injuries may be masked.

Conclusion

Stab wounds and gunshot wounds are the most common causes of penetrating trauma to the head and neck in the United States. For patients without indications for immediate surgical exploration, CTA has been demonstrated to have high sensitivity and negative predictive value for vascular injuries. CTA can also delineate extravascular injuries that may or may not be suspected on physical examination. Knowledge of management of penetrating neck injuries and their imaging characteristics is essential for making an accurate diagnosis and facilitating prompt treatment.

References

1. Núñez DB Jr, Torres-León M, Múnera F: Vascular injuries of the neck and thoracic inlet: helical CT-angiographic correlation. Radiographics 2004; **24**: 1087–1098, discussion 1099–1100. [Medline] [CrossRef]
2. Steenburg SD, Sliker CW, Shanmuganathan K, Siegel EL: Imaging evaluation of penetrating neck injuries. Radiographics 2010; **30**: 869–886. [Medline] [CrossRef]
3. Apffelstaedt JP, Müller R: Results of mandatory exploration for penetrating neck trauma. World J Surg 1994; **18**: 917–919, discussion 920. [Medline] [CrossRef]
4. Monson DO, Saletta JD, Freeark RJ: Carotid vertebral trauma. J Trauma 1969; **9**: 987–999. [Medline] [CrossRef]

5. Roon AJ, Christensen N: Evaluation and treatment of penetrating cervical injuries. J Trauma 1979; **19**: 391–397. [Medline] [CrossRef]
6. Schroeder JW, Baskaran V, Aygun N: Imaging of traumatic arterial injuries in the neck with an emphasis on CTA. Emerg Radiol 2010; **17**: 109–122. [Medline] [CrossRef]
7. Munera F, Danton G, Rivas LA, Henry RP, Ferrari MG: Multidetector row computed tomography in the management of penetrating neck injuries. Semin Ultrasound CT MR 2009; **30**: 195–204. [Medline] [CrossRef]
8. Osborn TM, Bell RB, Qaisi W, Long WB: Computed tomographic angiography as an aid to clinical decision making in the selective management of penetrating injuries to the neck: a reduction in the need for operative exploration. J Trauma 2008; **64**: 1466–1471. [Medline] [CrossRef]
9. Inaba K, Munera F, McKenney M, Rivas L, de Moya M, Bahouth H, Cohn S: Prospective evaluation of screening multislice helical computed tomographic angiography in the initial evaluation of penetrating neck injuries. J Trauma 2006; **61**: 144–149. [Medline] [CrossRef]
10. Stuhlfaut JW, Barest G, Sakai O, Lucey B, Soto JA: Impact of MDCT angiography on the use of catheter angiography for the assessment of cervical arterial injury after blunt or penetrating trauma. AJR Am J Roentgenol 2005; **185**: 1063–1068. [Medline] [CrossRef]
11. Woo K, Magner DP, Wilson MT, Margulies DR: CT angiography in penetrating neck trauma reduces the need for operative neck exploration. Am Surg 2005; **71**: 754–758. [Medline]
12. Núñez D Jr, Rivas L, McKenney K, LeBlang S, Zuluaga A: Helical CT of traumatic arterial injuries. AJR Am J Roentgenol 1998; **170**: 1621–1626. [Medline] [CrossRef]
13. LeBlang SD, Nuñez DB Jr: Helical CT of cervical spine and soft tissue injuries of the neck. Radiol Clin North Am 1999; **37**: 515–532, v–vi. [Medline] [CrossRef]
14. Shiroff AM, Gale SC, Martin ND, Marchalik D, Petrov D, Ahmed HM, Rotondo MF, Gracias VH: Penetrating neck trauma: a review of management strategies and discussion of the ‘No Zone’ approach. Am Surg 2013; **79**: 23–29. [Medline]
15. Bowen BC: MR angiography versus CT angiography in the evaluation of neurovascular disease. Radiology 2007; **245**: 357–360, discussion 60–61. [Medline] [CrossRef]
16. Kesser BW, Chance E, Kleiner D, Young JS: Contemporary management of penetrating neck trauma. Am Surg 2009; **75**: 1–10. [Medline]
17. Rathlev NK, Medzon R, Bracken ME: Evaluation and management of neck trauma. Emerg Med Clin North Am 2007; **25**: 679–694, viii. [Medline] [CrossRef]
18. Kuehne JP, Weaver FA, Papanicolaou G, Yellin AE: Penetrating trauma of the internal carotid artery. Arch Surg 1996; **131**: 942–947, discussion 947–948. [Medline] [CrossRef]
19. Meier DE, Brink BE, Fry WJ: Vertebral artery trauma: acute recognition and treatment. Arch Surg 1981; **116**: 236–239. [Medline] [CrossRef]
20. LeBlang SD, Nunez DB Jr: Noninvasive imaging of cervical vascular injuries. AJR Am J Roentgenol 2000; **174**: 1269–1278. [Medline] [CrossRef]
21. Bell RB, Osborn T, Dierks EJ, Potter BE, Long WB: Management of penetrating neck injuries: a new paradigm for civilian trauma. J Oral Maxillofac Surg 2007; **65**: 691–705. [Medline] [CrossRef]
22. Onat S, Ulku R, Cigdem KM, Avci A, Ozcelik C: Factors affecting the outcome of surgically treated non-iatrogenic traumatic cervical esophageal perforation: 28 years experience at a single center. J Cardiothorac Surg 2010; **5**: 46. [Medline] [CrossRef]
23. Young CA, Menias CO, Bhalla S, Prasad SR: CT features of esophageal emergencies. Radiographics 2008; **28**: 1541–1553. [Medline] [CrossRef]
24. Chen JD, Shanmuganathan K, Mirvis SE, Killeen KL, Dutton RP: Using CT to diagnose tracheal rupture. AJR Am J Roentgenol 2001; **176**: 1273–1280. [Medline] [CrossRef]
25. Buterbaugh JE, Erly WK: Paratracheal air cysts: a common finding on routine CT examinations of the cervical spine and neck that may mimic pneumomediastinum in patients with traumatic injuries. AJNR Am J Neuroradiol 2008; **29**: 1218–1221. [Medline] [CrossRef]