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REVIEW ARTICLE

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Imaging traumatic and nontraumatic neck emergencies in the adult

Abstract Many traumatic and nontraumatic conditions affecting the adult neck may present emergently. A prompt and accurate imaging assessment is vital to patient management in many of these conditions. In this review we will discuss the imaging assessment of both penetrating and blunt vascular and laryngeal trauma, infectious neck emergencies such as supraglottitis and septic thrombophlebitis, and nontraumatic airway conditions that may present emergently such as subglottic stenosis and angioneurotic edema.

Key words Neck – Emergencies – Trauma – Nontraumatic – Imaging

Introduction

The neck is a complex anatomic area that contains many vital structures in a relatively small area. In this review we will discuss emergencies which affect the adult neck (exclusive of the cervical spine) and their imaging correlates. The major categories that we will cover are trauma (with a focus on vascular and laryngeal trauma), infection, and nontraumatic airway emergencies. As this will bring up a diverse range of pathology, focused anatomic considerations and imaging recommendations will be reviewed in individual sections.

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Trauma

Vascular

The carotid and vertebral arteries are vulnerable to injury in the setting of blunt or penetrating trauma. Clinical criteria of vascular injury include a history of arterial bleeding or ongoing arterial bleeding, a large or expanding hematoma, a carotid bruit, decreased or absent carotid or upper extremity pulses, and the presence of neurologic abnormalities secondary to central nervous system ischemia [1]. Types of vascular injury that are commonly encountered include dissection, pseudoaneurysm formation, occlusion, arteriovenous fistula formation, and active hemorrhage with hematoma formation. The primary imaging modality in the setting of vascular trauma is catheter angiography, but in certain situations (see below) there may be a role for computed tomography (CT), CT angiography (CTA), magnetic resonance imaging (MRI), MR angiography (MRA), or duplex ultrasonography.

Penetrating trauma

Penetrating trauma typically results from gunshot or stab wounds and is more likely than blunt trauma to injure vessels. Hemorrhage, shock, and airway compromise secondary to hematoma are major factors causing death after penetrating injury. Central nervous system (CNS) ischemia is also a significant factor in morbidity and/or mortality after penetrating vascular injury. Patients with penetrating trauma should undergo anteroposterior and lateral radiography of the neck with markers on the entrance and exit wounds in order to assess the trajectory of the injury and to look for missile fragments, fractures, and foreign bodies [2]. Noncontrast CT may be indicated to assess injury to structures such as the cervical spine or larynx (see below), or to better assess the trajectory of a missile, but is not generally indicated to specifically assess the vasculature. If a CT scan is performed, soft tissue infiltration and hematoma may be identified. The CT also provides additional information about the path of injury, which may alter the work-up and prompt angiography. The potential role of contrast-enhanced spiral CTA has not been formally evaluated in the setting of penetrating neck trauma. It has recently been suggested [3] that CTA performs comparably to angiography or surgery in the diagnosis of penetrating vascular injury; however, CTA is limited in fine detail compared with conventional catheter angiography and is also subject to artifacts related to bone, retained metallic foreign bodies, and patient motion.

Angiography is frequently indicated to evaluate vascular injury, but its role is somewhat controversial and in evolution. Angiography is not performed in unstable patients, as they generally require emergent surgery. In stable patients, surgical exploration of all wounds penetrating the platysma was initially suggested in the 1950s in order to avoid missing asymptomatic injuries [4]. Because of a high rate of negative explorations and advances in imaging technology, angiography became the study of choice for all patients with penetrating neck injuries but without signs of arterial injury [5, 6]. However, this led to high utilization of arteriography and a high rate of negative studies.

At present, when considering the need for arteriography in the stable patient with a penetrating neck injury, the neck is divided into three zones (Fig. 1): zone I extends from the clavicle to the cricoid, zone II from the cricoid to the angle of the mandible, and zone III from the angle of the mandible to the base of skull [7]. Note that some authors define zone I as below the level of the sternal notch, with zone II extending from the sternal notch to the angle of the mandible [1], but these minor differences do not affect recommendations. Penetrating trauma to zones I and III usually mandates arteriography since (a) clinical evidence of vascular injury may be lacking because of collateral circulation, and (b) surgical exploration of these regions is difficult because of limitations to providing adequate surgical exposure and their inherent anatomic complexity (Fig. 2) [8]. Zone II is relatively accessible to physical examination, and multiple studies [9–11] have shown that findings on physical examination are good predictors of zone II arterial injury and can exclude injury in over 99% of patients. Some investigators do advocate arteriography in stable patients with zone II injuries and no definite evidence of vascular injury on physical examination if a missile trajectory crosses the path of a major vessel (Fig. 3) [11] or if the injury is transcervical [12]. Duplex sonography has also been proposed to evaluate stable patients with zone II injuries [13].

Additional potential advantages of angiography beyond simply diagnosing vascular injury include generation of a roadmap for the surgeon, temporary control of vascular injuries with balloons while surgical access is being obtained, and definitive control of bleeding in some cases with transcatheter embolization. The latter is particularly useful in zone III injuries and vertebral artery injuries [12] (Fig. 4). Vertebral artery injuries following penetrating trauma are relatively rare compared with carotid injuries. Because the vertebral artery is comparatively inaccessible surgically, however, suspected vertebral injury may be an additional indication for catheter angiography. Vertebral artery dissections or occlusions are usually managed by close clinical observation or possibly anticoagulation if other injuries allow, while pseudoaneurysms, arteriovenous fistulae, and extravasations discovered angiographically are usually managed by transcatheter embolization [14].

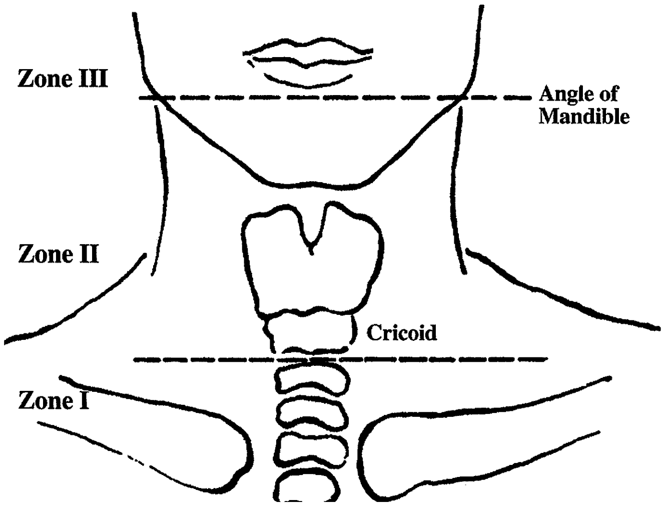


Fig. 1 Zonal anatomy of the neck. Zone I extends from clavicle to cricoid encompassing the root of the neck and thoracic inlet, zone II extends from the cricoid to the angle of the mandible, and zone III extends from the angle of the mandible to the base of the skull

When arteriography is performed in the setting of penetrating trauma, the most common findings are dissection, pseudoaneurysm formation, occlusion, and arteriovenous fistula formation. Pseudoaneurysms and arteriovenous fistulae may also present in a delayed fashion, as vascular spasm resolves or narrowed vessels (recanalize). The major angiographic features of carotid dissection are luminal stenosis, intimal flaps, and aneurysmal dilatation [15]. Carotid occlusion complicates 20% of dissections and is usually seen angiographically as a smooth tapering of the contrast column extending 1–3 cm above the carotid bifurcation (Fig. 5). Pseudoaneurysms appear as smooth or irregular contrast collections extending eccentrically from the vessel (Fig. 6), while arteriovenous fistulae result in poor arterial flow beyond the level of the fistulous communication and early filling of venous structures. Zonal anatomic contents and a guide to which vessels should be studied angiographically is provided in Table 1.

The most important clinical sequelae of penetrating vascular injury include hemorrhage and ischemia. Ongoing hemorrhage requires surgical or endovascular intervention to avoid shock and death. CNS ischemic injuries may be difficult to diagnose in the trauma patient

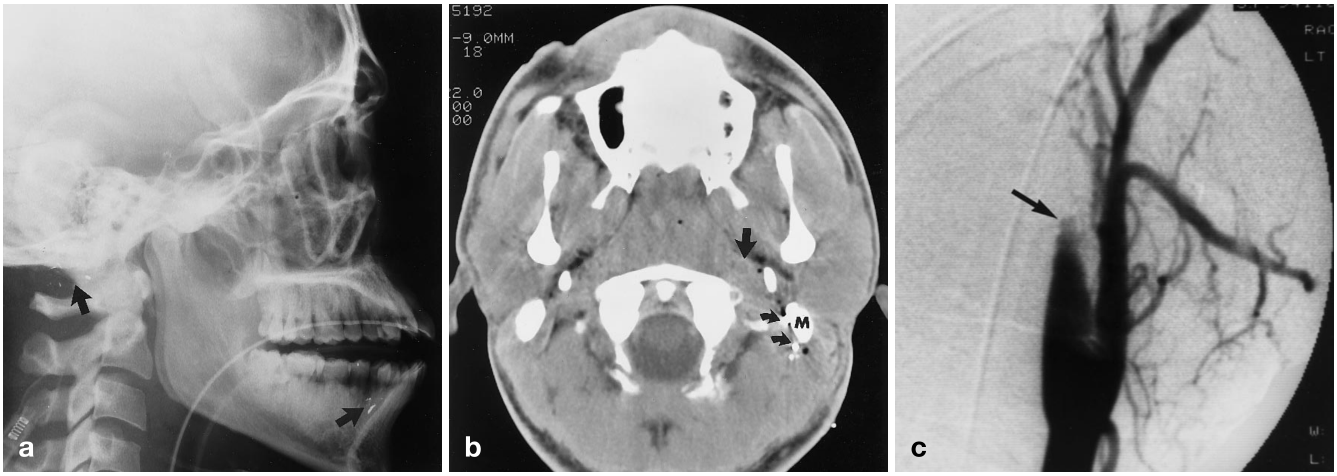


Fig. 2 a–c A young man sustained a gunshot wound to the neck. **a** A lateral plain film shows metallic fragments projecting over the mandible and adjacent to the mastoid tip *(arrows)*, consistent with zone III injury. **b** An axial image from a noncontrast CT scan demonstrates metallic fragments *(curved arrows)* medial to the left mastoid tip *(M)*. The pattern of air in the deep tissues and the presence of fragments near the mandible and mastoid as shown in **a** indicate that the trajectory of the missile passed close to the left internal carotid artery *(straight arrow)*. **c** A lateral projection from a left common carotid angiogram demonstrates occlusion of the left internal carotid artery *(arrow)*

Table 1 Contents of zones I, II, and III and guidelines for vascular assessment

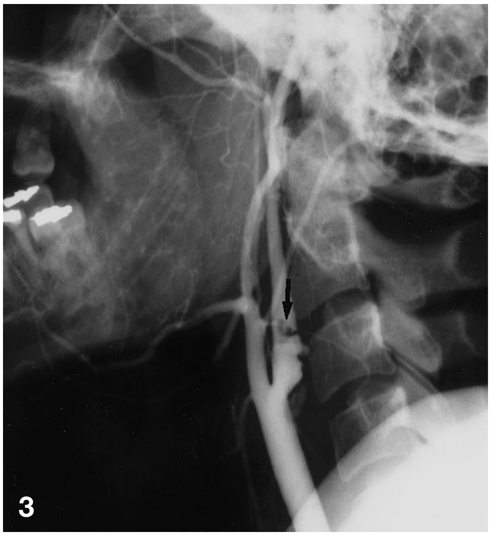
Zone	*Contents*	*Vascular studies*
Zone I	Origins of great vessels (innominate artery, subclavian arteries, proximal common carotid and vertebral arteries); subclavian and innominate veins; thoracic duct; brachial plexus	Arch aortography; selective injection of great vessels based on results of arch study and trajectory of penetrating object
Zone II	Distal common carotid arteries; proximal internal and external carotid arteries; mid vertebral arteries; internal jugular veins	Ipsilateral common carotid and vertebral injections; selective internal and external carotid artery injections if indicated; bilateral evaluation if injury crosses the midline; evaluation of collateral and intracranial circulation if a complete occlusion is present
Zone III	Distal cervical internal carotid arteries, external carotid artery branches, distal vertebral arteries	Same as zone II

who may be intubated and paralyzed (Fig. 7), or who may have concomitant head injuries. The index of suspicion must be high in this setting, and careful attention must be paid to subtle signs of cerebral ischemia on initial head CT scans. These signs include loss of the insular ribbon (indicative of edema in the insular cortex), hypodensity in the lentiform nucleus, sulcal effacement, and/or hyperdensity of the middle cerebral artery.

Blunt trauma

Blunt injury to the cervical vessels is far less common than penetrating trauma. Among all blunt trauma patients, the incidence of carotid arterial injury is approximately 0.32 % [16]. It usually results from motor vehicle accidents and severe hyperextension or abrupt flexion of the neck, though it may also occur with falls, sports injuries, and direct blows. An unusual cause of blunt arterial trauma is accidental or suicidal hanging [17]. Evidence of blunt arterial trauma can be easily missed on initial examination for many reasons, especially if it is clinically unsuspected: (a) there are few if any external signs of injury; (b) it may be masked by more obvious injuries; and (c) its manifestations may be attributed to concomitant head injuries. Additionally, results of an initial head CT are often normal (or interpreted as such [18]), and there may be a delay in the development of neurologic signs [19]. Vertebral artery injuries are not uncommon in the setting of acute cervical spine trauma [20], though most are clinically occult unless the injury is bilateral or the nontraumatized vertebral artery is hypoplastic.

The most common vascular abnormality in the setting of blunt trauma is dissection, presumably related to traction on the carotid or vertebral artery followed by a tear in the intima or media with intramural hemorrhage. This is often followed by platelet aggregation and thrombus formation, with subsequent embolization. Vascular occlusion, pseudoaneurysm formation, arteriovenous fistula formation, or avulsion may also occur. Clinically the earliest sign of blunt vascular injury is a change in the level of consciousness or mental status, often accompanied by focal neurologic deficits due to thromboembolic phenomena or hypoperfusion [15]. The manifestations of cerebral ischemia appear within 24 h in 50 % of cases, but they may be quite delayed



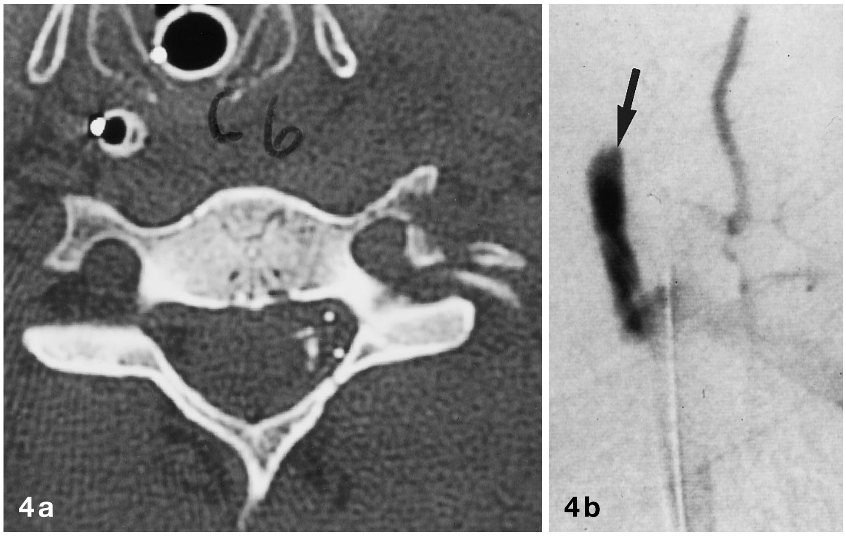


Fig. 3 A young male stabbed in zone II was stable and had no definite signs of vascular injury on physical examination. Because the trajectory of the wound suggested that the carotid artery was at risk, an angiogram was performed. A lateral view from a common carotid artery injection demonstrates irregularity of the wall of the internal carotid artery as well as an intimal flap *(arrow)*. (Case courtesy of Scott Evans, MD, Denver, Colo.)

Fig. 4 a, b A young man was shot in the neck. **a** An axial image from a noncontrast CT scan demonstrates metallic fragments within the spinal canal, as well as a comminuted fracture of the left transverse process of C6, with compromise of the foramen transversarium at this level. **b** A frontal projection from the late phase of a left subclavian artery injection demonstrates occlusion of the left vertebral artery *(arrow)* and the left costocervical trunk. Coils were subsequently placed via an endovascular approach to occlude the stump of the vertebral artery (not shown)

Fig. 5 A young woman was stabbed in the neck. Lateral projection from a common carotid artery injection demonstrates a tapering occlusion of the internal carotid artery *(arrow)*, most consistent with carotid dissection

[8]. Diagnosis of blunt carotid injury prior to symptomatic presentation appears to improve outcome, as it allows for prompt institution of anticoagulation (if feasible with regard to other injuries) [16]. Other treatment options include revascularization, bypass, and/or vessel occlusion.

In the setting of blunt vascular injury, MRI/MRA may be a useful imaging technique because of its exquisite sensitivity to dissection [8]. The combination of MRA and axial T1-weighted images with fat saturation is highly sensitive and specific for diagnosing the luminal narrowing and intramural hematoma that typically accompany vascular dissection [21] (Fig. 8). Spiral CTA may have a role in this setting as well [22]. Conventional catheter angiography may also be useful (Fig. 9) to assess collateral circulation, perform intra-arterial thrombolysis to treat complicating emboli, and undertake endovascular occlusion in the setting of pseudoaneurysm or arteriovenous fistula formation [23, 24]. Triage decisions over which patients with blunt trauma require vascular evaluation remain difficult. In a recent series in which patients with blunt trauma significant enough to warrant arch aortography were evaluated for carotid injury, 2.5 % of examinations demonstrated clinically unsuspected injuries [16].

Larynx and trachea

The larynx and trachea may be injured in the setting of blunt or penetrating trauma, and these injuries may be immediately life-threatening. Common etiologies include motor vehicle accidents, gunshot wounds, and assaults. Associated injuries to cervical vessels and the cervical spine are common.

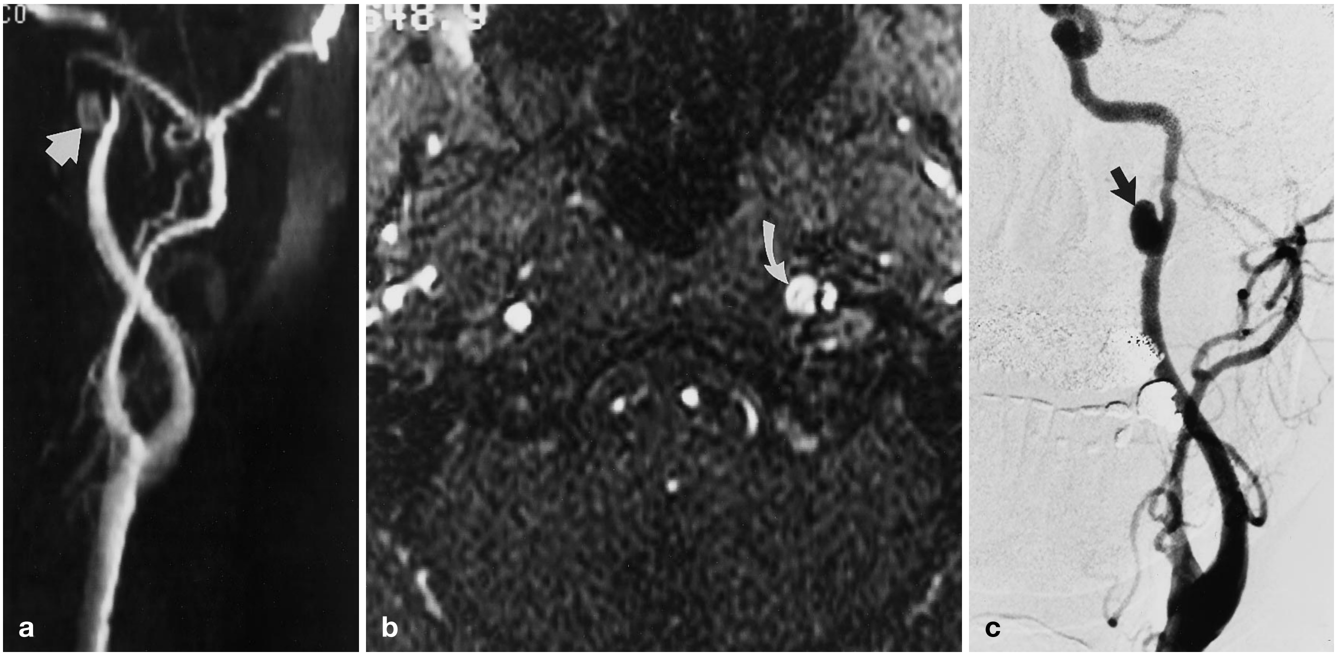


Fig. 6 a–c A patient was stabbed with a knitting needle. The depth of penetration of the weapon was uncertain. Several weeks later he experienced transient right-sided weakness and presented for evaluation. **a** A maximum intensity projection image from a 2-D time of flight MR angiogram demonstrates narrowing of the distal cervical internal carotid artery and an adjacent, less intense, rounded mass *(arrow)* suggestive of a pseudoaneurysm. **b** An axial source image from the MR angiogram demonstrates irregular narrowing of the internal carotid artery consistent with a chronic dissection, as well as the adjacent mass which demonstrates flow-related enhancement and is consistent with a patent pseudoaneurysm *(arrow)*. **c** A frontal projection from a conventional catheter angiogram during injection of the left common carotid artery confirms dissection of the distal cervical segment of the internal carotid artery and an associated pseudoaneurysm *(arrow)*

Fig. 7 a–c A 46-year-old male was stabbed in the neck and chest. He was intubated and paralyzed at the scene of the accident and was then transported to the hospital. When his paralysis was lightened, it was noted that he was not moving his right side. **a** An oblique view from a left common carotid artery injection demonstrates abrupt occlusion of the internal carotid artery *(arrow)*. **b** An oblique view of the intracranial circulation during injection of the right internal carotid artery shows cross-filling of anterior cerebral artery branches via a patent anterior communicating artery, but essentially no flow into the left middle cerebral artery *(arrow)*, consistent with thrombotic or thromboembolic occlusion. **c** An axial T2-weighted image of the brain from an MR scan obtained 12 h after the injury demonstrates infarction in the territory of the left middle cerebral artery *(arrows)*

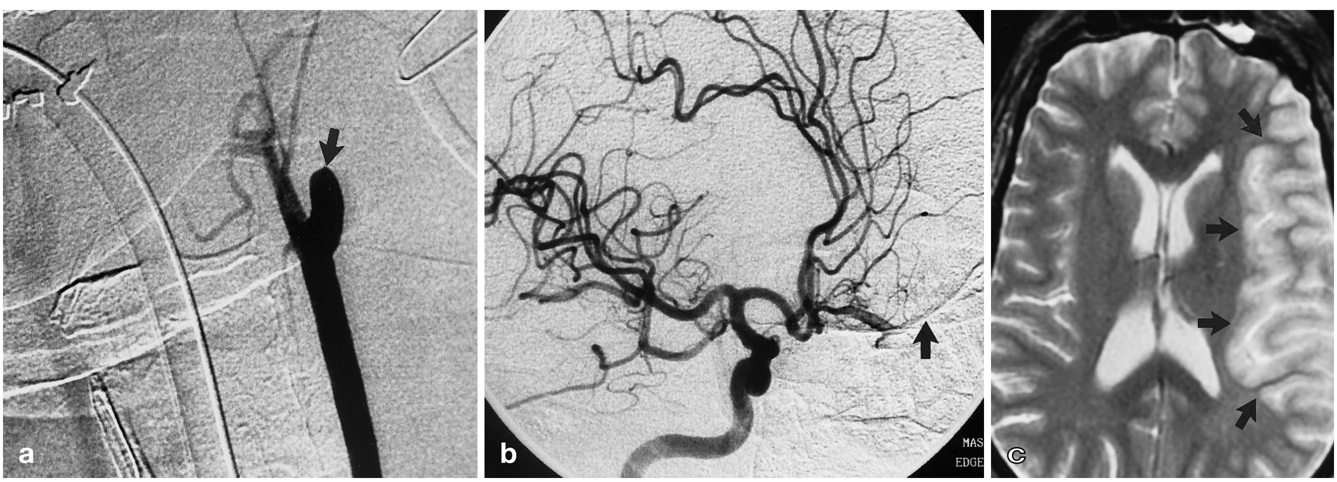


Fig. 8 a, b A 39-year-old woman complained of headache and transient left visual changes after colliding with a tree while skiing. On examination she was noted to have left ptosis and miosis, consistent with Horner's syndrome. **a** An oblique coronal maximum intensity projection image from a 3-D time of flight MR angiogram demonstrates subtle irregular narrowing of the left internal carotid artery at and below its entrance into the petrous bone *(arrows)*. Note that the patient only appears to have a single anterior cerebral artery as the two vessels are superimposed over each other. **b** An axial T1-weighted image with fat saturation demonstrates an eccentric crescent of hyperintense material consistent with subintimal/mural hematoma *(arrow)* which is slightly narrowing the lumen of the left internal carotid artery. This finding is diagnostic of carotid dissection

Penetrating trauma

Penetrating laryngotracheal injuries are uncommon (8% of penetrating neck injuries) but are associated with significant morbidity and mortality [25]. Airway injuries may be isolated or may be associated with injury to the upper digestive tract or cervical vessels. The diagnostic evaluation of these patients must be individualized based on the type and severity of injury but often includes a combination of laryngoscopy, esophagoscopy and bronchoscopy; contrast esophagography (penetrating injury of the larynx always carries the possibility of concomitant injury to the esophagus); plain films, and/or CT scanning. These modalities serve to assess trajectories, locate retained foreign bodies, and assess the presence of subcutaneous air and fractures. Conventional angiography is indicated if concurrent vascular injury is suspected (see above).

Blunt trauma

Blunt trauma to the larynx may result in laryngeal contusion, dislocation of the cricoarytenoid joint, fracture of the hyoid bone, fracture of the thyroid and/or cricoid cartilages, or laryngotracheal separation [2]. Clinical symptoms include pain, hoarseness or aphonia, dyspnea, hemoptysis, dysphagia, and/or odynophagia. Clinical signs include crepitus secondary to subcutaneous air and loss of normal anatomic landmarks due to swelling. In stable patients with relatively minor injuries, the larynx is often evaluated with CT scanning to diagnose laryngeal fractures and dislocations. CT may also demonstrate edema, hematoma, and subcutaneous emphysema. CT scanning should extend from the hyoid to the inferior cricoid ring, with slices no more than 2 mm in thickness; spiral scanning mode and three-dimensional reconstructions may be useful in some cases [26]. Patients with more severe injuries typically require surgery and are examined during surgical exploration, though preoperative CT scanning may be useful to determine the extent of injury and to serve as a roadmap during repair of complex laryngotracheal injuries [27–30].

Laryngeal fractures may involve the thyroid and/or cricoid cartilages. Because of the size and more anterior location of the thyroid cartilage, it is fractured more frequently than the cricoid cartilage. The thyroid cartilage may suffer vertical, paramedian, transverse, or comminuted fractures, though most are vertically oriented [29] (Fig. 10). A horizontal fracture may theoretically be missed with CT scanning, and coronal or sagittal reformations may be useful if the source images are thin enough (preferably 1 mm) to avoid stair-step artifacts during reconstruction. Fractures of the thyroid cartilage are commonly associated with glottic and supraglottic soft tissue injuries, including tearing or avulsion of the epiglottis. The arytenoid cartilages may be dislocated, appearing anteriorly displaced and medially rotated. Fractures of the cricoid cartilage are often associated with thyroid cartilage fractures. Cricoid fractures tend to break the ring in two places, but the second fracture may be difficult to detect [26]. The fractures usually occur anteriorly or laterally where the cartilage is thinnest, with posterior cricoid fractures less common. Subglottic soft tissue swelling may be a helpful clue to the presence of a cricoid fracture. In general, laryngeal fractures are more difficult to detect in young patients in whom the laryngeal cartilages are not well ossified.

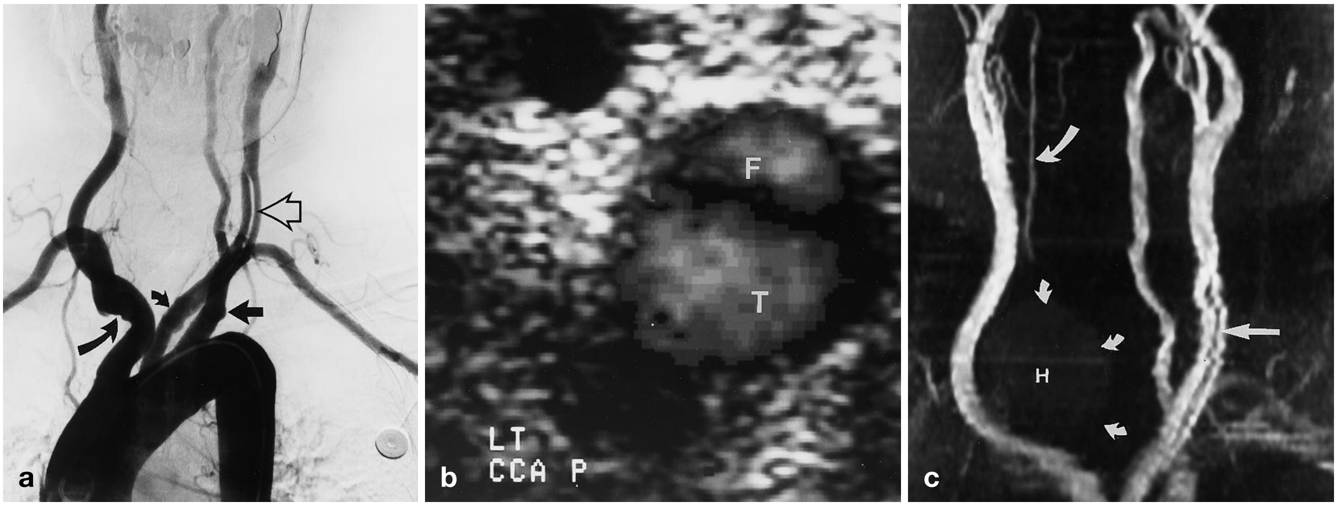


Fig. 9 a–c A 66-year-old woman suffered a high-speed motor vehicle accident during which her air bag inflated. An arch aortogram was performed. **a** A right posterior oblique image from an arch aortogram demonstrates an intimal flap in the left common carotid artery *(open arrow)*, with flow in both true and false lumens. In addition, irregular outpouchings of contrast were noted involving the proximal subclavian artery *(straight solid arrow)*, left common carotid artery *(short curved solid arrow)*, and brachiocephalic artery *(long curved solid arrow)*. These abnormalities were confirmed in other views. Additionally, the right vertebral artery was noted to be occluded proximally and to reconstitute distally via muscular collaterals. **b** A follow-up ultrasound study was obtained to assess flow in the left common carotid artery. Transverse images from a color Doppler study show flow in both the true *(T)* and false *(F)* lumens. **c** A coronal maximum intensity projection image from a 2-D time of flight MR angiogram similarly demonstrates the persistent intimal flap *(straight arrow)*, with flow in both true and false lumens. In addition, a portion of the reconstituted right vertebral artery is seen *(long curved arrow)*. Also noted is a faintly bright, rounded mass projecting superior to the right brachiocephalic artery *(short curved arrows)*. This represents mild methemoglobin "shine-through" from a resolving traumatic thyroid hematoma *(H)*

Other structures

The pharynx and/or esophagus may be disrupted by blunt or penetrating injuries, or in some cases by barogenic trauma. Overall the most common cause of esophageal trauma is iatrogenic, with injury occurring during routine esophagogastroduodenoscopy (incidence 0.1 %) or during balloon dilatation of esophageal strictures (incidence as high as 10 %) [31, 32]. These injuries are often suspected and/or clinically evident at the time of injury. Traumatic noniatrogenic injuries may not be obvious on initial evaluation, but as the infectious complications may be fatal, it is important to have a high index of suspicion in order to diagnose them in a timely fashion. A pharyngeal or esophageal contusion, usually caused by blunt trauma, results in pain and mild or moderate dysphagia and can often be managed conservatively [2]. Rupture or laceration may be produced by blunt or penetrating trauma and results in pain, dysphagia, hemoptysis, and subcutaneous emphysema. Untreated injuries may present subacutely with abscess formation and mediastinitis. The diagnostic evaluation often requires plain radiography to look for free air and retropharyngeal thickening, pharyngoesophagoscopy and/or esophagography to more accurately localize injury, and CT scanning to look for foreign bodies and extraluminal fluid collections. The overall morbidity and mortality of noniatrogenic traumatic pharyngeal and/or esophageal injuries is approximately 20 %, due both to the difficulty of diagnosing and managing the injury itself and the severity of associated vascular, laryngotracheal, and thoracic injuries.

Neural structures in the neck may also be injured. Any neurologic structure may be injured with penetrating trauma, while blunt trauma typically injures the spinal cord, phrenic nerves, and recurrent laryngeal nerves (especially if laryngotracheal disruption occurs). The physical examination is the most important part of the evaluation, though plain radiographs may be useful to evaluate for missile fragments and determine the trajectory of penetrating injuries, while chest radiography can assess the position of the diaphragm [2]. The evaluation of neural injuries is outside the scope of this review.

Nontraumatic hemorrhage

Nontraumatic hemorrhage into the soft tissues of the neck is a life-threatening emergency that generally occurs in the setting of infection or neoplasm, particularly as an unusual delayed complication of primary or salvage therapy for extensive and/or recurrent squamous cell carcinoma of the head and neck [33]. "Carotid blow-out" (CBO) is operationally defined as either an episode of acute hemorrhage (usually transoral or transcervical) or exposure of a portion of the carotid artery in a patient who has previously undergone surgical resection for squamous cell carcinoma. An exposed artery (threatened CBO) is managed surgically with coverage by healthy tissue. A short-lived acute hemorrhage that resolves spontaneously or with simple surgical packing

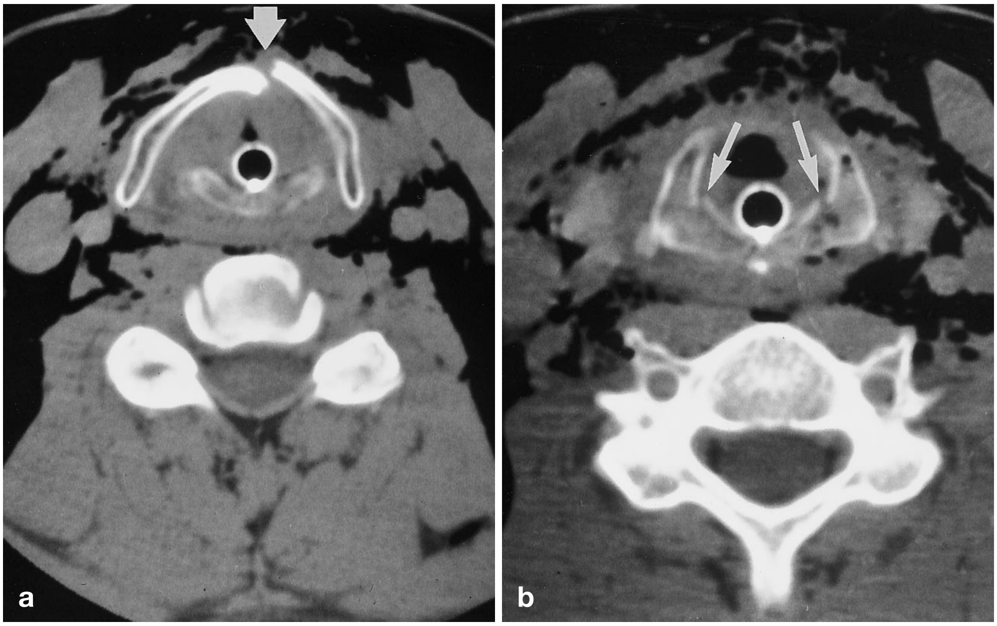


Fig. 10 a, b A young man was kicked in the throat and then developed hoarseness and dyspnea. **a** An axial image filmed in bone window from a CT scan demonstrates a vertical, slightly displaced fracture of the thyroid cartilage *(arrow)*. Massive subcutaneous emphysema is present. **b** A more inferior image from the CT scan demonstrates bilateral fractures of the cricoid ring *(arrows)*

(impending CBO) is generally managed endovascularly, with the vessel occluded permanently if the patient tolerates a preceding balloon test occlusion. In cases of impending CBO where the bleeding is due to small pseudoaneurysms of distal external carotid branches, coil occlusion may be used. Acute profuse hemorrhage that is not self-limited and not well controlled with surgical packing (acute CBO) has a high morbidity and mortality rate, even with emergent endovascular or surgical therapy [33]. Other unusual causes of nontraumatic hemorrhage include carotid artery rupture due to infection [34] and massive hemorrhage from highly vascular neoplasms or thyroid nodules [35]. Internal jugular vein rupture has also been recognized as a potential complication following complex head and neck surgical procedures [36].

Infection

A number of infectious processes may present emergently, generally because of airway compromise but also with sepsis or vascular compromise. We will review the clinical correlates, imaging recommendations, and imaging findings of the major infectious neck emergencies.

Supraglottitis

Adult epiglottitis or supraglottitis is a relatively uncommon but potentially life-threatening condition that has an incidence of 1.8 cases/100,000 adults/year [37] and should be considered in the differential diagnosis of the patient presenting with a sore throat and dysphagia. The term "supraglottitis" is preferred to describe the adult form of the disease since involvement may extend to the soft palate, base of tongue, and vallecula, while there is wide variability in the degree of epiglottic edema [38]. Anatomically, the mucous membrane that covers the supraglottis is loosely attached to the lingual surface of the epiglottis and tightly bound to the laryngeal surfaces of the epiglottis and arytenoid cartilages [39]. This arrangement fosters accumulation of inflammatory fluid in the supraglottis, resulting in a dramatic decrease in the diameter of the laryngeal inlet and a substantial increase in the work of breathing. Because of the larger diameter and greater rigidity of the adult airway, supraglottitis has a more variable rate and incidence of progression to airway obstruction than in children. A high degree of airway narrowing is usually well tolerated until late in the course of illness in adults, but if the narrowing becomes critical, unpredictable precipitous airway obstruction may develop [40].

Adult supraglottitis is often preceded by a viral upper respiratory infection. These patients have a persistent sore throat and then develop dysphagia and/or odynophagia. Unlike in children where the usual pathogen is *Hemophilus influenzae* type B, a wide variety of pathogens have been implicated in adult disease, including streptococcal and staphylococcal species, anaerobes, and gram-negative organisms, as well as certain viruses such as *Herpes simplex virus* types 1 and 2 [39]. There appears to be a slightly increased incidence of supraglottitis in the human immunodeficiency virus (HIV)-positive population. In this group the disease has a more aggressive course and patients are predisposed to the development of emphysematous epiglottitis [41, 42].

Once the diagnosis of supraglottitis is considered, adults should undergo indirect or direct fiberoptic laryngoscopy for definitive diagnosis as, unlike children, they will usually tolerate a full examination without laryn-

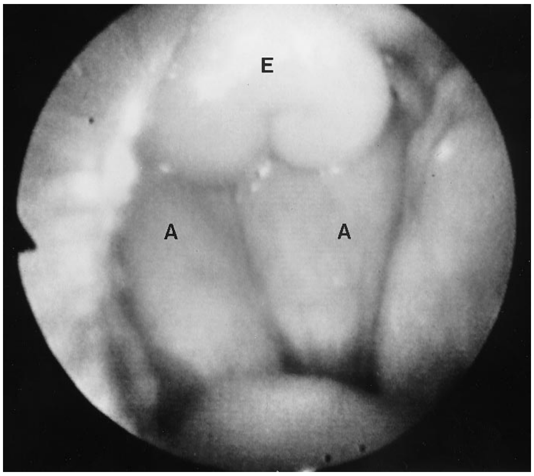


Fig. 11 Fiberoptic pharyngoscopy in a patient with supraglottitis demonstrates marked swelling of the epiglottis *(E)* and aryepiglottic folds *(A)*

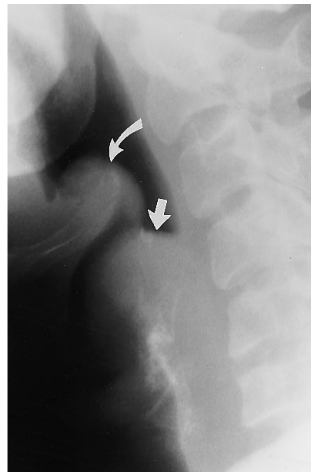


Fig. 12 A lateral plain film of the neck in a patient with supraglottitis demonstrates marked swelling of the epiglottis *(curved arrow)* and aryepiglottic folds *(straight arrow)*

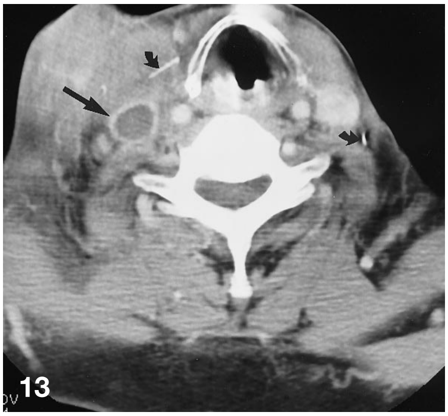
gospasm or airway obstruction (Fig. 11). The use of a soft tissue lateral plain film of the neck is controversial: it is predictive of supraglottitis but does not reliably substitute for direct examination [43]. However, if a patient has minimal symptoms or the diagnosis is unclear, radiography may prove helpful. The classic plain film findings include enlargement of the epiglottis and aryepiglottic folds, giving a "swollen thumb" appearance (Fig. 12). On occasion, gas in the soft tissues may be seen due to emphysematous epiglottitis. According to Nemzek et al. [38], several defined parameters should aid in the plain film diagnosis of acute epiglottitis in adults: normally, the ratio of the width of the epiglottis to the width of C4 should not be greater than 33 %; the ratio of the prevertebral soft tissue to C4 should not exceed 0.5; and the ratio of the width of the hypopharyngeal airway to the width of C4 should be less than 1.5.

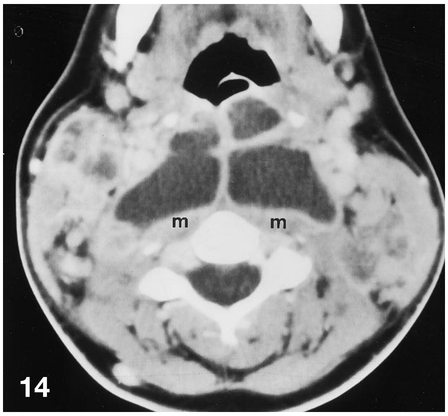
Though the diagnosis of supraglottitis is made on the basis of clinical history and physical examination, occasionally with supporting evidence from plain radiography, CT may be helpful in some situations to exclude other conditions that may have a similar presentation, such as peritonsillar abscess or lingual tonsillitis, or to evaluate for complications such as epiglottic abscess formation. The most common CT findings in supraglottitis include: thickening of the epiglottis, aryepiglottic folds, and true and false vocal cords; obliteration of the preepiglottic fat; thickening of the platysma; and reticulation of subcutaneous fat [41]. Note that CT scanning should be performed only in patients with stable or secured airways.

Once the diagnosis of supraglottitis has been established, patients are treated with antibiotics, hydration, systemic analgesics, and often steroids. Opinions differ about airway management. All agree that patients with severe airway symptoms (stridor, dyspnea, sitting bolt upright) or drooling should be intubated immediately [40, 44]. Some recommend securing the airway as soon as the diagnosis is confirmed even if the patient is minimally symptomatic [43, 45], but most recommend extremely close monitoring, usually in the intensive care unit, and serial laryngeal examinations [40, 44, 46]. Mortality rates of supraglottitis vary in the literature from 0 to 20 % [43, 44, 47], with the lowest mortality rates appearing to correlate with early diagnosis and prompt institution of therapy.

Septic thrombophlebitis

Septic thrombophlebitis of the internal jugular vein is the most common vascular complication of deep neck infection. This complication is particularly common in intravenous drug abusers, and the most common causative organisms are *S. aureus* and β-hemolytic streptococci. If noncontrast CT is obtained, the thrombosed vessel may appear abnormally dense. Contrast-enhanced CT scanning (generally the study of choice) demonstrates low density in the vascular lumen, intense enhancement of the wall of the vein due to engorgement of the vasa vasorum ("halo sign"), and inflammatory changes around the vein with poor definition of soft tissue planes (Fig. 13). The thrombosed vein may be enlarged. If MRI is performed, the normal flow void will be absent, though thrombus may be mimicked by slow flow in the jugular vein. Septic thrombophlebitis is usually managed with hydration and antibiotics; anticoagulation is controversial, and surgical ligation and/or excision of the involved vessel are rarely necessary. A related entity is suppurative thrombophlebitis of the jugular vein in the presence of oropharyngeal infection, also known as Lemierre's syndrome [48, 49], which is often complicated by septic embolization to the lungs, brain, and other organs (metastatic abscesses). This is thought to result from septic thrombophlebitis of tonsillar veins with extension to the internal jugular vein.





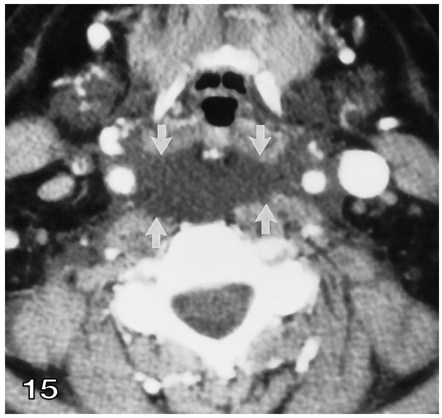


Fig. 13 A contrast-enhanced CT scan was obtained in an intravenous drug user who complained of fever and neck swelling and tenderness. There is marked edema of the right sternocleidomastoid muscle, and inflammatory changes in adjacent soft tissues. The thrombosed right internal jugular vein *(straight black arrow)* demonstrates low density in the vascular lumen and enhancement of the surrounding wall. Several linear metallic densities *(short curved arrows)* represent needle fragments

Fig. 14 A contrast-enhanced CT scan demonstrates a large, multiloculated collection with a well-defined enhancing rim in the retropharyngeal space, consistent with retropharyngeal abscess. The prevertebral muscles *(m)* are compressed by the large anterior collection. Low-density cervical lymph nodes are also present. At surgery, 20 ml frank pus was aspirated from the retropharyngeal space

Fig. 15 A contrast-enhanced CT scan in a patient with thrombosis of the superior vena cava and right internal jugular vein demonstrates abnormal low-density material in the retropharyngeal space (marginated by *arrows*), extending into the carotid space bilaterally, but without encapsulation or peripheral enhancement. This was felt to represent severe retropharyngeal edema and resolved spontaneously when the patient's venous obstruction was relieved

Abscess/deep neck space infections

Neck abscesses may present emergently when they compromise vital structures such as vessels or the airway, or when they extend to contiguous areas such as the mediastinum.

Retropharyngeal abscess

Retropharyngeal abscess (RPA) is far more common in children than in adults. In children, RPA is often preceded by a viral upper respiratory infection, pharyngitis, or otitis media. These infections lead to adenopathy, and RPA is thought to develop from suppuration of retropharyngeal lymph nodes. The fact that these nodes regress in adulthood probably accounts for the low incidence of RPA in adults. Adult RPA is typically associated with surgical procedures or blunt trauma to the neck, spread of infection from an adjacent focus, or foreign bodies [50], and is seen more commonly in patients with underlying illnesses such as diabetes, cancer, or HIV infection. Adult patients with RPA typically present with sore throat, dysphagia, neck pain, and, less commonly, stridor. Infections are often polymicrobial, with streptococcal and staphylococcal species as well as anaerobes. The posterior pharyngeal wall may be visibly swollen on physical examination, but this is unusual.

Symptoms out of proportion to the oropharyngeal examination in a patient with sore throat and an unrevealing physical examination may prompt a lateral plain film of the neck. Retropharyngeal calcific tendinitis, a self-limiting process which is in the clinical differential diagnosis, can be assessed with a lateral plain film (which reveals prevertebral soft tissue swelling and an amorphous radiodensity anterior to the C1 and C2 vertebral bodies) [51]. The lateral plain film in cases of RPA typically demonstrates nonspecific thickening of the prevertebral soft tissues and loss of the normal cervical lordosis. In the appropriate clinical setting, measurements greater than 7 mm at C2 and 22 mm at C6 are abnormal and are considered to strongly support the diagnosis of RPA [52]. Contrast-enhanced CT scan of the neck is the imaging study of choice, as it distinguishes RPA from retropharyngeal cellulitis or edema and defines the superior and inferior extent of the process; note that the chest may need to be included in the examination depending on the extent of the process. A retropharyngeal abscess appears as a low-density collection with an enhancing periphery (Fig. 14). The posterior pharyngeal wall is anteriorly displaced and the prevertebral muscles appear posteriorly displaced and compressed. If the RPA is due to diskitis/osteomyelitis, there may be associated erosion of vertebral endplates and possibly an epidural collection as well, and the cervical spine and spinal canal should be carefully examined in all cases of RPA. Retropharyngeal cellulitis appears as soft tissue thickening and infiltration of fat without a well-defined low attenuation collection. Retropharyngeal edema may be quite impressive and mass-like, but does not have an enhancing capsule (Fig. 15).

Complications of RPA follow from the anatomy of the retropharyngeal space. The retropharyngeal alar space, also known as space 3 of Grodinsky [53], is a potential space bounded anteriorly by the pharyngeal constrictor muscles and their investing fascia and posteriorly by the alar layer of prevertebral fascia. Laterally it is bounded by the carotid sheaths, superiorly by the skull base, and inferiorly by fusion of the anterior and posterior layers of fascia at the level of C7 or T1. Behind the retropharyngeal space is the danger space (space 4 of Grodinsky), which extends into the mediastinum and often as far inferiorly as the diaphragm. Infection can track over long distances in these spaces, and complications of RPA include mediastinitis, pleural effusion and/or empyema, epidural abscess and vertebral osteomyelitis, and atlantoaxial separation [54].

Peritonsillar abscess

Peritonsillar abscess (PTA) is the most common deep infection of the neck, with 45,000 cases per year in the United States. The PTA is a collection of pus typically located between the fibrous capsule of the tonsil medially and the superior pharyngeal constrictor muscle [54]. The parapharyngeal space lies immediately deep to the superior pharyngeal constrictor muscle and provides a route for extensive superoinferior spread of inflammation if the process extends to the parapharyngeal space. PTA occurs when bacteria penetrate from the tonsillar crypts through the tonsillar capsule and into the peritonsillar space. Patients typically present with severe pain, fever, dysphagia, trismus, change in voice ("hot potato voice") and occasionally airway compromise. Examination demonstrates erythema and enlargement of the tonsil, with medial deviation of the tonsil and soft palate. Imaging is not required when the clinical history and physical findings are typical of PTA. Contrast-enhanced CT scanning may be useful in recurrent or refractory cases to guide therapy and assess for complications. CT findings of PTA include tonsillar swelling, a focal low-density collection deep to the tonsil surrounded by an enhancing rim, and edema of adjacent structures (soft palate, medial pterygoid muscle, parapharyngeal space). Complications of PTA include spread to other deep neck spaces with abscess formation, as well as vascular thrombosis.

Ludwig's angina

The term "Ludwig's angina" refers to an extensive cellulitic infection of the floor of the mouth, without frank abscess formation. This entity acquired its name in the preantibiotic era, when the infection would dissect inferiorly into the mediastinum and the patient would present with angina-like chest pain. By definition, this process never involves only one space and usually is bilateral. It produces gangrene with serosanguinous putrid infiltration but little or no frank pus, involves connective tissue, fascia, and muscle but not the glandular structures, and is spread by continuity rather than via lymphatics [34, 55]. Most cases are related to dental infections, though they may also be due to laceration of the floor of the mouth, salivary calculi, and open mandibular fractures. Infections are typically polymicrobial, with streptococcal or staphylococcal species combined with anaerobes.

Patients with Ludwig's angina are usually acutely ill with fever, dysphagia, odynophagia, tachypnea, dyspnea, and/or stridor. Brawny induration of the soft tissues of the submental neck is present, and the floor of the mouth is edematous. The process may progress rapidly over the course of a few hours and is a clinical emergency. Complications include tongue retrusion, airway compromise, deep neck abscess formation if the mylohyoid muscle is penetrated, extension of infection into the mediastinum, and aspiration of purulent material into the lungs [56]. Plain radiographs may be useful to demonstrate soft tissue edema and the presence of gas-forming organisms. Contrast-enhanced CT scan should not be performed until the airway is stabilized, but it may be useful in patients in whom the diagnosis is equivocal as well as to identify drainable collections (Fig. 16), document the presence of gas-forming organisms, and evaluate underlying dental disease [55].

Infected embryologic cysts

Branchial cleft cysts (BCC) and thyroglossal duct cysts (TGDC) most commonly present in children and young adults, but may be a cause of recurrent neck infections at any age [56, 57]. Embryologically the thyroglossal duct extends from the foramen cecum of the posterior tongue, descending in close approximation to the body of the hyoid bone, to the pyramidal lobe of the thyroid gland. Residual functioning secretory epithelium anywhere along this tract gives rise to a cyst that may cause respiratory obstruction or fistula formation if it becomes secondarily infected. Classically patients have a history of a soft mass in the midline of the neck near the hyoid bone that moves with swallowing; infection leads to swelling, erythema, and pain. Complications of infection include deep neck cellulitis and abscess formation, respiratory obstruction, fistula formation, and aspiration. Infected TGDCs are treated with antibiotics, with emergent incision and drainage reserved for patients who fail to improve or who manifest progressive symptoms. When the acute infection has resolved, a definitive Sistrunk procedure is performed (excision of the TGD cyst and tract, including the central hyoid bone). Contrast-enhanced CT scan is generally adequate for evaluating a simple or infected TGDC (Fig. 17), but MRI in the sagittal plane may demonstrate the entire course of the thyroglossal duct back to the level of the foramen cecum [58].

Similar considerations apply to the management of BCCs, which may also become infected and be complicated by deep neck abscesses, respiratory obstruction, and aspiration. Second BCCs account for approximately 85 % of these lesions and typically occur along the anterior border of the sternocleidomastoid muscle, posterior

Fig. 16 A contrast-enhanced CT scan in a patient with Ludwig's angina was obtained several days after initial drainage (note surgical drain anteriorly, *arrow*) because the patient was doing poorly. The scan demonstrates multiple loculated collections with peripheral enhancement consistent with multiple abscesses. Following the CT scan the patient was brought back to the operating room for further drainage

Fig. 17 A contrast-enhanced CT scan of the neck in a patient with midline erythema, tenderness, and swelling demonstrates a midline mass with central low attenuation and a thick, irregular, enhancing rim. Cellulitic changes are noted in the overlying skin and subcutaneous fat. The patient was treated with intravenous antibiotics, and when the acute inflammation had resolved, a thyroglossal duct cyst was resected

to the submandibular gland [59]. An infected BCC typically shows peripheral enhancement on contrast-enhanced CT scan as well as inflammatory changes in the adjacent soft tissues.

Necrotizing fasciitis

Necrotizing fasciitis is a term used to describe a severe, acute, and potentially life-threatening condition that is caused by streptococcal or mixed bacterial infection involving both aerobes and anaerobes and that propagates continuously within soft tissues [60, 61]. The elderly and immunocompromised are usually affected, but necrotizing fasciitis may be observed in otherwise healthy patients. Involvement of the head and neck is relatively uncommon. The onset is often insidious with nonspecific swelling, erythema, and fever. Early in its course, distinction from cellulitis is often impossible. Regardless of the site affected, the clinical course is characterized by septic complications that may develop within hours, and mortality rates of up to 75% are reported. Antibiotics alone are ineffective, and prompt aggressive surgical exploration and drainage are required [62]. At surgery, there is typically extensive necrosis of subcutaneous fat, fascia, and muscle; fluid collections are consistent with liquefied necrotic tissue rather than true abscesses. If the process is not adequately controlled, frank gangrene typically sets in after 4–5 days, and death follows soon thereafter [63].

Contrast-enhanced CT scanning may be very useful to distinguish between necrotizing fasciitis and cellulitis, to identify the extent of involvement for the surgeon, to define and/or rule out abscess formation, and to identify patients in need of further débridement after initial surgery. Constant CT features of necrotizing fasciitis include diffuse thickening and infiltration of the cutis and subcutis (cellulitis), diffuse enhancement and/or thickening of superficial and deep cervical fasciae (fasciitis), enhancement and thickening of the platysma, sternocleidomastoid, and/or strap muscles (myositis), and fluid collections in multiple neck compartments. Inconstant CT features include gas collections, mediastinitis, pleural or pericardial effusions, disruption of the platysma from focal necrosis, and septic thrombosis of the internal jugular vein [60]. It has recently been suggested that MRI may be useful to differentiate necrotizing fasciitis from cellulitis by directly demonstrating deep fascial involvement [64]; this distinction is critical as early and adequate surgical débridement and fasciotomy in necrotizing fasciitis are associated with improved survival, but early clinical differentiation between these two entities may be difficult.

Noninfectious, nontraumatic airway compromise

We have reviewed traumatic and infectious processes that may compromise the airway and thus present emergently. In the final section we will discuss a number of miscellaneous entities that may present with airway compromise and in which there may be a role for imaging.

Foreign body

Foreign body ingestion or aspiration is far more common in children than adults. In adults, the most common upper aerodigestive tract foreign bodies include accidentally ingested fish bones and traumatically dislodged dental prostheses or teeth. Symptoms may be anywhere between minimal and acutely life-threatening and include dysphagia, odynophagia, referred otalgia, dyspnea/stridor related to partial airway obstruction, and respiratory arrest if airway obstruction is complete [65].

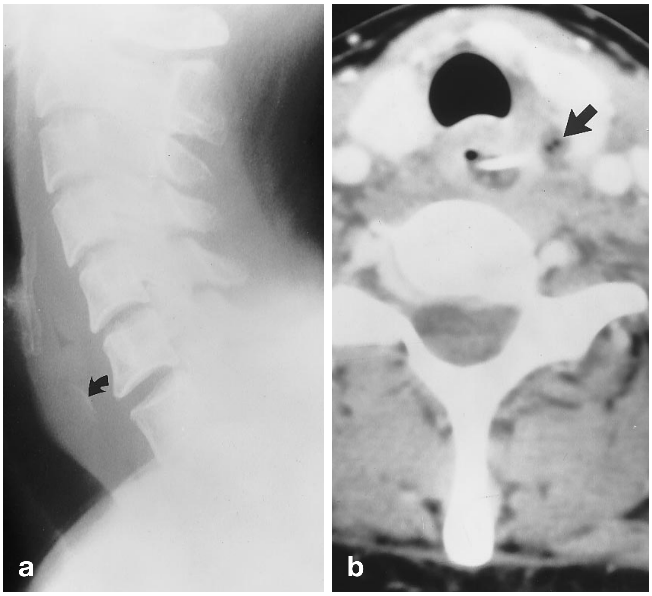


Fig. 18 a, b. A 40-year-old woman presented to the emergency room complaining of dysphagia after eating fish for dinner. **a** A lateral plain film of the neck demonstrates thickening of the lower cervical prevertebral/retropharyngeal tissues. A questionable abnormal curved density is noted *(arrow)*. **b** A contrast-enhanced CT scan in the same patient confirms the presence of a foreign body which has penetrated the wall of the esophagus. A small gas and fluid collection is noted adjacent to the esophagus *(arrow)*, consistent with abscess formation. At surgery, this collection was drained and a fish bone was removed from the esophagus

Because foreign bodies in the larynx and trachea may be rapidly fatal if not immediately removed, imaging is generally not performed or is limited to anteroposterior and lateral films of the soft tissues of the neck and a frontal chest radiograph. With esophageal foreign bodies, posteroanterior and lateral chest radiography is performed; if the level of obstruction is not readily apparent, having the patient swallow a cotton ball soaked with barium or a barium tablet may help localize the foreign body. CT scanning may be useful to localize small foreign bodies such as fish bones that are not visible on plain films, and is also useful to identify complications of foreign body ingestion or removal such as perforation and abscess formation (Fig. 18).

Neoplasms

Neoplasms of the neck and upper aerodigestive tract usually enlarge slowly, coming to clinical attention before the onset of respiratory distress. Most obstructing lesions are hypopharyngeal or transglottic squamous cell carcinomas, but obstructing masses may also arise from the thyroid, trachea, or esophagus. Nerve sheath tumors may also result in airway obstruction, typically when large and/or multiple as in neurofibromatosis type I or II. Symptoms such as hoarseness, dysphagia, odynophagia, and/or hemoptysis are usually present for weeks or months prior to the onset of respiratory distress. Neoplasms of the subglottic larynx and trachea, which are uncommon, may be relatively asymptomatic except for progressive shortness of breath and stridor [66]. Anaplastic carcinoma of the thyroid may enlarge rapidly and cause acute respiratory distress [67]. Nonneoplastic masses such as goiters may also present with acute respiratory distress when the airway reaches a critical level of narrowing (Fig. 19). Tracheotomy is usually necessary to secure the airway in the setting of obstructing head and neck cancer. Once the airway is secured, cross-sectional imaging with CT or MRI is useful to determine the extent of tumor invasion.

Bilateral vocal cord paralysis

Bilateral vocal cord paralysis is an uncommon cause of upper airway obstruction that may be seen in a variety of clinical settings including: thyroid or parathyroid surgery; malignancy of the thyroid, trachea, or esophagus; bilateral carotid endarterectomy; bilateral jugular foramen syndrome; rheumatoid arthritis; and a variety of neurologic disorders such as infarction, multiple sclerosis, and failure of a ventriculoperitoneal shunt [66]. Often a patient has tolerated a unilateral cord paralysis without difficulty, and then the loss of the second cord leads to respiratory distress. Some patients tolerate bilateral vocal cord paralysis well with only minimal symptoms at rest until a respiratory infection compromises the residual airway and acute dyspnea and stridor develop [68].

In patients without a clear-cut etiology of cord paralysis, imaging may be useful to localize the level of pathology. In general, if other cranial nerves are affected as well as the tenth cranial nerves, then imaging should extend from the skull base through the larynx as likely levels of pathology include the brain stem, jugular foramina, and/or upper carotid space. If only the tenth cranial nerves are affected, then pathology is likely to lie below the level of the hyoid, and imaging should be extended into the upper mediastinum to assess the full course of the recurrent laryngeal nerves [69]. A contrast-enhanced CT scan generally suffices for imaging of the neck and superior mediastinum, while MRI is preferred for assessing the brain stem and skull base (Fig. 20).

Subglottic stenosis

Subglottic stenosis may be idiopathic but is more commonly acquired, and is usually related to previous endotracheal intubation. Stridor and dyspnea typically develop 1–3 months after extubation, and older patients are often initially diagnosed with congestive heart failure if their only symptom is dyspnea on exertion. Other causes of subglottic stenosis include prior blunt laryngotracheal trauma, Wegener's granulomatosis, tubercu-

Fig. 19 An elderly woman developed respiratory distress and was emergently intubated. A neck mass was palpated clinically, and the patient was sent for CT scan. A contrast-enhanced CT scan of the neck demonstrates a large, heterogeneous mass involving the thyroid gland *(arrows)* consistent with a multinodular goiter

Fig. 20 A middle-aged woman with exertional stridor was found to have bilateral true vocal cord paralysis as well as abnormal palatal function. An axial post-gadolinium T1-weighted image with fat saturation demonstrates bilateral carotid space masses *(arrows)*, consistent with bilateral paragangliomas

losis, sarcoidosis, and polychondritis [70]. The diagnosis is usually made by history, indirect laryngoscopy, and rigid endoscopy under general anesthesia. Plain films, particularly with tomography, may demonstrate a smooth, tubular narrowing of the subglottic airway. CT scanning, particularly with spiral technique and very thin sections allowing high-quality multiplanar reformations, may be useful to determine the length of the stenosis and to evaluate the peritracheal tissues.

Angioedema

Angioedema is characterized by the sudden onset of nonerythematous, nonpruritic swelling that may be idiopathic, hereditary, or triggered by external factors. The edema often involves the lips, tongue, oropharynx, and larynx and may result in fatal airway compromise. The hereditary form is due to a low level of C1 esterase inhibitor [71], a component of the complement cascade, and is dominantly inherited. Angioedema associated with the use of angiotensin converting enzyme (ACE) inhibitors [72–74] affects 1/1000 patients within the first week of therapy. As neither hereditary nor ACE inhibitor-associated angioedema are IgE-mediated, epinephrine, steroids, and antihistamines may be ineffective and endotracheal intubation or tracheostomy may be required in the setting of acute airway compromise. Imaging should not be attempted until the airway is se-

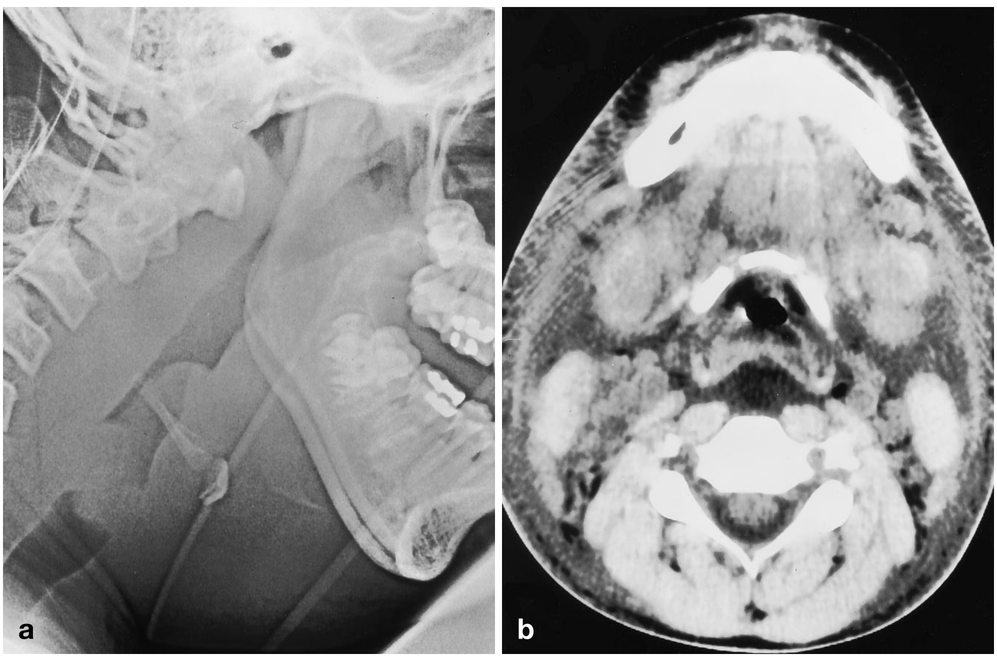


Fig. 21 a, b A patient who had been taking an angiotensin converting enzyme-inhibitor for one week presented to the emergency room complaining of lip and tongue swelling and difficulty swallowing. **a** A lateral digital scout radiograph from a CT scan demonstrates diffuse edema involving the tongue, submental tissues, epiglottis, aryepiglottic folds, and prevertebral/retropharyngeal space. **b** An axial image from a noncontrast CT scan demonstrates diffuse soft tissue edema, with a more focal fluid collection in the retropharyngeal space. Note that the patient should not have been brought to the CT scanner with an unprotected airway cured. If imaging is performed because the etiology of airway compromise is in question, a contrast-enhanced CT scan will demonstrate marked symmetric edema of oropharyngeal, supraglottic, and/or glottic tissues without focal mass or fluid collection (Fig. 21).

Conclusion

A variety of traumatic and nontraumatic processes may result in a neck emergency. These conditions frequently require a coordinated response by trauma and emergency medicine physicians, otolaryngologists, vascular surgeons, and radiologists. We have reviewed the major traumatic, hemorrhagic, infectious, and miscellaneous lesions that present emergently in the adult neck, exclusive of the cervical spine and neural structures, with a focus on radiological evaluation and interpretation.

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