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SURGICAL SYMPOSIUM CONTRIBUTION

Penetrating Cervical Trauma

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David V. Feliciano

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Abstract Patients with penetrating wounds to the neck present with overt symptoms and/or signs or are asymptomatic or modestly/moderately symptomatic. With overt symptoms and/or signs, immediate resuscitation and an emergency operation are appropriate. Asymptomatic patients or those with modest or moderate symptoms and/or signs undergo observation or a diagnostic evaluation to avoid the 45 % "negative" exploration rate documented in the past (denominator = all patients). Asymptomatic patients with penetration of the platysma muscle, but no signs of a visceral or vascular injury, should undergo serial physical examinations every 6–8 for 24–36 h before discharge. Noncontrast CT does not add to the accuracy of serial physical examinations. In stable patients with a variety of modest/moderate symptoms or signs possibly related to an injury to the carotid artery, CT-arteriography has become the diagnostic modality of choice. Patients with possible injuries to the cervical esophagus are often still evaluated with a Gastrografin swallow and, if needed, a "thin" barium swallow prior to fiberoptic esophagoscopy. CT-esophagograms are likely to replace these time-honored studies in the near future. Over 85 % of patients with injuries to the trachea present with overt symptoms or signs, while the remainder have historically been evaluated with laryngoscopy and fiberoptic bronchoscopy. Again, cervical multislice CT is likely to replace these studies. Operative repair of the carotid artery with 6–0 polypropylene sutures requires heparinization and shunting on rare occasions. Both the trachea and esophagus are repaired with 3–0 absorbable sutures, and tracheostomy and esophageal diversion are used in only large and/or complex injuries. Sternal head or sternocleiodomastoid interposition flaps are used when combined visceral and vascular injuries are present.

Introduction

Zones of the neck

The original and best description of the Zones of the neck was by Monson, Saletta, and Freeark from Cook County Hospital in 1969 [1]. This classification is based on the difficulties in exposure for certain cervical vascular wounds and includes 3 Zones as follows: (I) inferior to the clavicles and manubrium sterni and includes all structures passing through the thoracic outlet; (II) between the thoracic outlet and the angle of the mandible; and (III) between the angle of the mandible and the base of the skull.

Adapted with permission from Feliciano DV, Vercruysse GA: Neck. In Mattox KL, Moore EE, Feliciano DV (eds): Trauma, Seventh Edition. New York; McGraw Hill, 2013, pp 414–429.

D. V. Feliciano (✉)
Division of General Surgery, Department of Surgery, Indiana University Medical Center, 545 Barnhill Drive, #509, Indianapolis, IN 46202, USA
e-mail: davfelic@iupui.edu

Management of patients: overt symptoms or signs group

Hemorrhage ("hard" sign of vascular injury): zone I or low zone II

The most common overt symptoms or signs in all three Zones of the neck are related to injuries to vascular

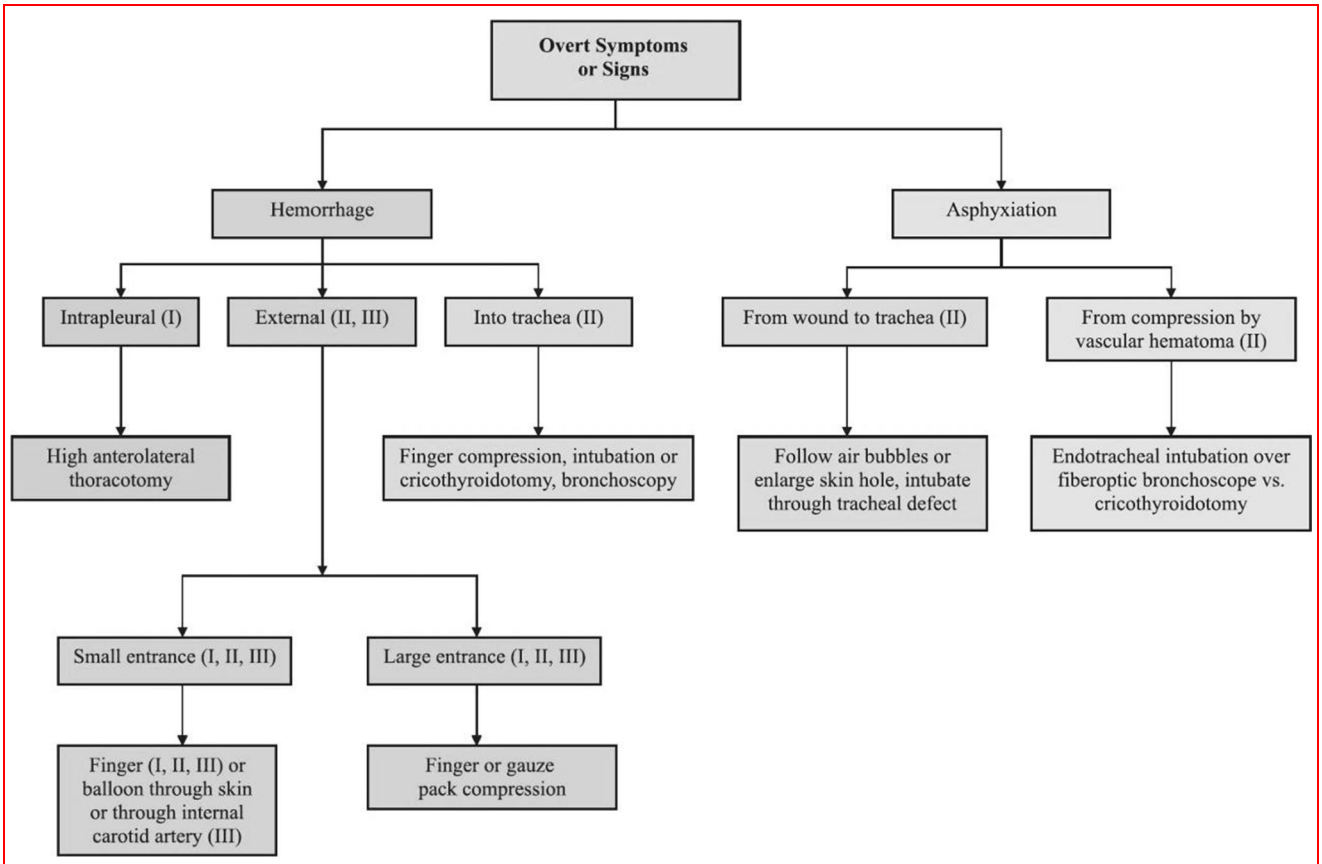


Fig. 1 Algorithm for management of patients with overt symptoms or signs (from [2]. Used with permission)

structures and/or the larynx or trachea. On occasion, a patient will present with exsanguinating external hemorrhage from the thoracic outlet (Zone I) or the low anterior neck (Zone II) after sustaining a penetrating wound. Manual compression over a small skin hole from a stab or gunshot wound with a finger or gauze pad is appropriate. With a larger skin wound from a knife slashing, laceration with glass or a shotgun wound, it may be possible to blindly insert two or three fingers to compress the bleeding vessel. On occasion, it may be necessary to rapidly enlarge the skin wound with a scalpel or scissors prior to insertion of the fingers. If blind finger compression in the wound is unsuccessful, tight packing of the open area with 3 or 4 in. gauze is appropriate to avoid exsanguination during transport to a distant operating room (Fig. 1).

In the operating room, a decision on which incision to use (median sternotomy with cervical extensions, high anterolateral thoracotomy, supraclavicular with clavicul-otomy or partial claviculectomy) for managing hemorrhage from Zone I depends on the location of the wound, whether compression or packing has controlled the hemorrhage, and the patient's hemodynamic status [2]. An example would be a wound that is thought to injure the common carotid artery or internal jugular vein right in the thoracic outlet or in the upper aspect of the superior mediastinum (Fig. 2). If compression or packing has controlled the hemorrhage, an experienced surgeon may choose to perform a standard oblique cervical incision in Zone II to reach that side of the superior mediastinum. When hemorrhage is poorly controlled in the outlet or intrapleural exsanguination is thought to be present (injury to proximal subclavian vessels) on the left side, a more aggressive approach is necessary. Such a patient should undergo a fourth intercostal space left anterolateral thoracotomy above the male nipple. This will allow for pack compression and/or direct clamping of the injured vessel in the superior mediastinum, thoracic outlet, or extrapleural location of the subclavian vessels. When there is a right lower cervical wound with poorly controlled hemorrhage from the thoracic outlet or presumed intrapleural hemorrhage, a bilateral anterolateral thoracotomy may need to be performed. Hemorrhage is controlled through the right thoracotomy, while cross-clamping of the descending thoracic aorta can be accomplished through the left thoracotomy.



Fig. 2 End-to-end anastomosis of the right common carotid artery (between the tips of the forceps) just above the bifurcation of the innominate artery was performed through a cervical incision in a patient with a shotgun wound of the anterior neck (from [6]. Used with permission)

Hemorrhage: zone II

External hemorrhage from a penetrating wound in Zone II is managed with direct compression with a finger or gauze pad. As previously noted, a slash or shotgun wound can be managed with insertion of a gauze pack through the defect. A unilateral track of a missile or knife wound is approached with an ipsilateral oblique incision along the anterior border of the sternocleidomastoid muscle. A bilateral track mandates oblique incisions on right and left or a high anterior transverse incision with oblique extensions as needed. When arterial or mixed arterial venous and hemorrhage is obviously present, exposure and control of the common carotid artery at the inferior end of the incision are appropriate before the area of hemorrhage is exposed.

Hemorrhage: zone III

Finger compression over the rare wound in Zone III is occasionally unsuccessful in controlling hemorrhage from the internal carotid artery as it is interior to the mandible. If significant hemorrhage continues to occur despite manual compression, balloon catheter tamponade is indicated [3]. The skin defect is widened with a hemostat in the emergency room, and a 16 or 18-French bladder catheter is inserted as far as it will go. The balloon is inflated, and the patient is moved to the operating room. If a hematoma rapidly develops in the area of the balloon during transport or if hemorrhage continues to occur around the balloon, the Foley balloon is deflated in the operating room and a #3 or #4 Fogarty balloon catheter is inserted into the missile or stab track. Sequential advancement and inflation of the Fogarty balloon are performed until hemorrhage ceases [4]. The catheter is then sutured to the skin with the balloon inflated.

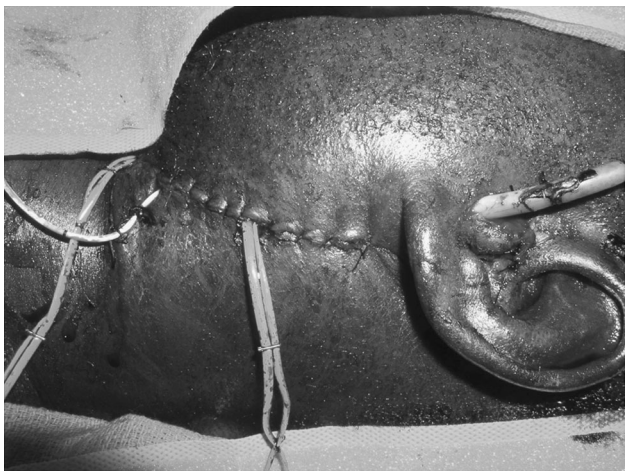


Fig. 3 Fogarty and Foley balloon catheter tamponade of a presumed injury to the *left* internal carotid artery from a stab wound anterior to the ear (from [5]. Used with permission)

In several patients in the author's experience, transwound balloon catheter tamponade only partially controlled external hemorrhage in the operating room. An ipsilateral anterior oblique cervical incision is then made, the common carotid artery is exposed, and this vessel is then followed superiorly to the internal carotid artery. After proximal and distal control of this artery is obtained, a 6–0 polypropylene suture is placed in a purse string fashion in the wall. Through a small arteriotomy, another #3 or #4 Fogarty balloon catheter is inserted, passed superiorly, and sequentially inflated until hemorrhage ceases [5] (Fig. 3).

Whenever balloon catheter tamponade is used to control hemorrhage from the internal carotid artery at the base of the skull, further information is needed to determine the next step in the patient's management. Bilateral CT carotid arteriograms are performed to localize the area of injury, its accessibility, and the status of crossover flow from the contralateral internal carotid artery. This is followed by a baseline EEG, CT of the brain, and insertion of an intracranial pressure monitor should moderate cerebral edema be present. Inadequate crossover arterial flow to the hemibrain or significant changes on the EEG on the side of the balloon tamponade mandates revascularization [6]. In the modern era, the insertion of an endovascular stent graft to

control hemorrhage and restore ipsilateral cerebral blood flow is the procedure of choice in compromised patients [7].

A patient with adequate carotid crossover flow after balloon tamponade is kept normotensive with a 100 % oxygen saturation level, and cerebral edema is treated in the usual fashion. The balloon is removed in the operating room 24–72 h after insertion in the hemodynamically stable patient.



Fig. 4 Large pulsatile cervical hematoma from an injury to the *right* common carotid artery caused airway distress before intubation

Airway compromise

A penetrating wound in Zones I or II may injure the larynx or trachea and lead to asphyxiation or aspiration. A major injury to the airway is likely if a patient has a change in voice, tachypnea, hemoptysis, or early cyanosis. A patient with these symptoms and a wound in proximity to the larynx should be managed by attempted intubation by an anesthesiologist or emergency medicine attending physician. Failure of intubation after one or two attempts or rapid deterioration of the patient with hypoxemia and hypotension should prompt a cricothyroidotomy. A #8 tracheostomy tube is inserted in a man, while a smaller tube may all that can be inserted in a woman. Once the patient's hypoxemia is corrected, transport to the operating room is necessary. Hemostasis is then obtained, a possible

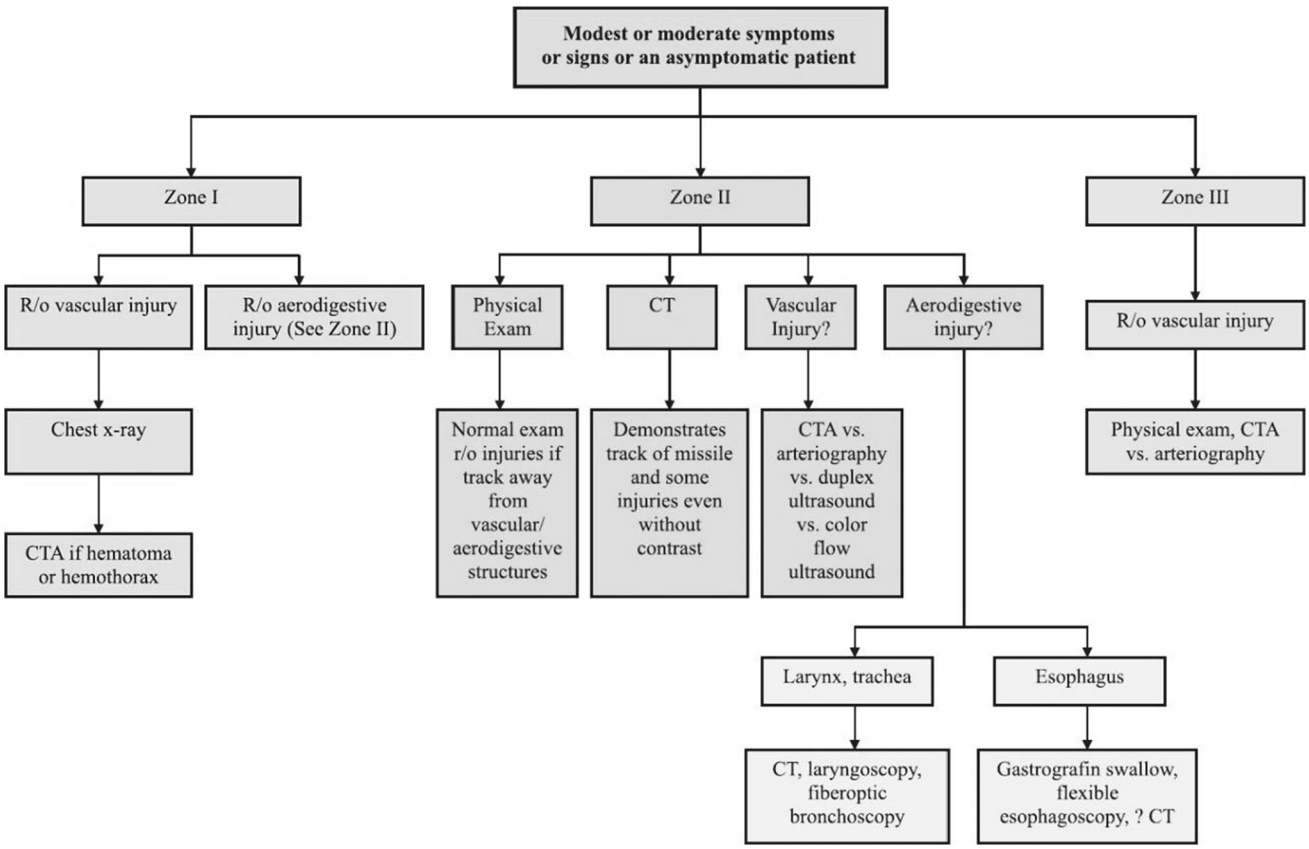


Fig. 5 Algorithm for evaluation of patients who are asymptomatic or who have modest or moderate symptoms or signs (from [2]. Used with permission)

repair is performed, and fiberoptic bronchoscopy is necessary.

A wound inferior to the larynx and a continuing air leak in addition to the symptoms mentioned above are presumptive evidences of an injury to the trachea. One attempt at endotracheal intubation is permitted. Should this fail, a patient in distress is managed by enlarging the skin wound with or without local anesthesia. Following the air leak, an endotracheal or anode tube is inserted into the tracheal defect or into the distal end of a transected trachea. When this maneuver cannot be performed, an anterior cervical incision and formal tracheostomy are performed.

Cervical airway compromise may occur from deviation or compression of the trachea caused by a hematoma from an adjacent vascular injury, as well (Fig. 4). If there is time, the patient should be moved to the operating room for an attempt at fiberoptic intubation by an anesthesiologist. A patient in severe distress should obviously undergo a standard cricothyroidotomy in the emergency center. No attempt is made to expose or drain the lateral cervical hematoma as exsanguinating hemorrhage may occur.

Another mechanism leading to compromise of the cervical airway is the presence of adjacent vascular and tracheal wounds. Aspiration of blood into the airway can occur rapidly in this uncommon situation. Vigorous compression should be placed on the wound as endotracheal intubation is attempted. Failure to intubate or an impending cardiopulmonary arrest mandates an emergency room cricothyroidotomy. After rapid transport of the patient to the operating room for control of the vascular injury, repairs as needed are performed along with fiberoptic bronchoscopy to clear the aspirated blood.

Evaluation of patients who are asymptomatic or who have modest or moderate symptoms or signs

Zone I

A hemodynamically stable patient without airway distress who has a penetrating wound in Zone I is evaluated much as any patient with a penetrating thoracic wound—i.e., a surgeon-performed thoracic ultrasound is performed to determine if pericardial blood (cardiac tamponade), a hemothorax, or a pneumothorax is present. A "normal" ultrasound is followed by a chest X-ray to track the missile and determine if any hematomas are present. A normal physician examination and chest X-ray essentially exclude a vascular injury around the thoracic outlet [8, 9]. If a hematoma is present on the chest X-ray, a follow-up screening CT is then performed to see if the aerodigestive system must be evaluated in addition to the vascular system. A CT-arteriogram will then document the presence of and localize a vascular injury to allow the surgeon to plan an operative approach (Fig. 5).

Zone II

It has long been recognized that the historic policy of operating on asymptomatic patients with stab wounds through the platysma muscle in Zone II results in an unacceptable "negative" exploration rate [10]. Continuing experience has confirmed that even patients with modest or moderate symptoms or signs, especially with stab wounds in Zone II, will only have a "therapeutic" cervical exploration 55–65 % of the time. Therefore, a selective rather than a mandatory operative approach is the standard of care in asymptomatic patients and in those with modest or moderate symptoms or signs [11–13].

Definitions/presentations

Depending on the source, *asymptomatic* patients are defined as those in whom there is penetration of the platysma muscle in Zone II, but there are no symptoms nor signs of an injury to the vascular or aerodigestive systems. *Modest or moderate symptoms or signs of a vascular injury* ("soft signs") would be a history of bleeding from the wound at the scene or during transport, proximity of the wound to the carotid artery or jugular vein, or the presence of a nonexpanding hematoma. *Modest or moderate symptoms or signs of an injury to the larynx or trachea* would be, as previously described, a change in voice, hoarseness, palpable crepitus, hemoptysis, air leaking through the wound, or cervical or mediastinal air on X-rays. *Modest or moderate symptoms or signs of an injury to the pharynx or esophagus* would be deep cervical pain, hematemesis, dysphagia, odynophagia, a positive sip test (pain with swallowing a sip of water), or cervical (retropharyngeal or retroesophageal) or mediastinal air on X-rays.

Physical examination

Physical examination is quite accurate in ruling out vascular or visceral injuries in asymptomatic patients with platysma penetration from a stab wound in Zone II. The same is true for through-and-through gunshot wounds in the lateral area of the anterior neck (under sternocleidomastoid muscle) away from the trachea and esophagus. A duplex ultrasound or CT-arteriogram can be performed if proximity to the carotid artery is a concern. Otherwise, patients undergo physical examination every 6–8 h for 24–36 h before discharge.

CT

CT has become almost routine in the evaluation of stable patients with penetrating cervical wounds and the absence of an overt presentation as previously described. Most experienced trauma surgeons, however, agree that it adds little to the evaluation of asymptomatic patients with a normal physical examination [14]. It does demonstrate the path of a penetrating wound to reassure the surgeon that there is no proximity to a vascular or aerodigestive structure [15].

Arterial diagnostic studies

Because of the historic 3–5 % risk of an arterial injury in a patient presenting with a previously described "soft sign" after a wound in an extremity (may not require surgery), there has always been a concern about a similar issue with cervical wounds [16]. In addition, it is assumed that a combination of "soft signs" such as proximity of a penetrating wound and a small hematoma would increase the risk that a subtle arterial injury is present. For this reason, the presence of "soft signs" of a vascular injury after a penetrating cervical wound usually prompts an arterial diagnostic study. Examples of such studies would be *digital subtraction arteriography (old standard), duplex ultrasonography, color flow Doppler, and CT-arteriography*. The obvious disadvantages of digital subtraction arteriography are the delays related to having the interventional radiology team return to the hospital, the invasive nature of the study, and the dye load in patients with recent hypotension from trauma. Duplex ultrasound, a combination of real-time brightness (B)-mode imaging and pulsed velocimetry, and color flow Doppler are highly accurate in diagnosing cervical arterial injuries [17–19]. Ideally, these studies should be performed by a registered vascular technologist (RVT) or a vascular surgeon with RVT training and/or certification. The availability of such individuals to perform the needed studies is limited in certain trauma centers.

CT-arteriography has become the standard of care for evaluating possible penetrating wounds to cervical arteries over the past 15 years [20–23]. It is performed rapidly at the time of cervical CT, and the accuracy with modern multislice helical scanners is equivalent to that of contrast arteriography in the past.

Esophageal diagnostic studies

In patients with any of the symptoms or signs of a possible esophageal injury, especially a positive sip test, further work-up is necessary. This is because proximity of a missile track, injury to adjacent structures, or local edema may be the cause of symptoms or signs thought to be related to an esophageal injury.

At the present time, there are not enough data on the accuracy of CT-esophagograms in evaluating patients with possible penetrating injuries of the esophagus. Therefore, the time-honored studies of a contrast swallow examination followed by flexible esophagoscopy, if needed, are still utilized in many trauma centers. Gastrografin (diatrizoate meglumine and diatrizoate sodium solution), a water soluble iodinated solution, is the initial contrast agent of choice to evaluate the esophagus. Because it is hyperosmotic, it can cause pulmonary edema, pneumonitis, or death if aspirated. It remains a popular diagnostic choice, however, as the accuracy of detecting an esophageal injury has ranged from 57 to 80 % in the past [2, 24, 25]. Because false-negative Gastrografin examinations occur, "thin" barium contrast is used for the follow-up study or even as the initial contrast agent in a few centers [2, 24, 25]. Should both these studies be normal, flexible esophagoscopy is then performed in the operating room or in an endoscopy suite under intravenous sedation. Flexible esophagoscopy alone had an accuracy of 97 and 99.3 % in detecting esophageal perforations in two studies in the past 18 years [26, 27]. The combination of contrast studies and flexible esophagoscopy has an accuracy approaching 100 % in diagnosing esophageal perforations after penetrating trauma.

Laryngotracheal diagnostic studies

The majority of patients with wounds to the larynx and over 85 % of patients with wounds to the trachea have overt symptoms related to the injury or to other vascular or esophageal injuries [28]. In the few remaining patients with the symptoms or signs previously described, the symptom may point out the location of injury. For example, a fracture of the thyroid cartilage with an associated rupture of the thyroepiglottic ligament (glottis injury) would cause hoarseness or stridor. Such patients should undergo laryngoscopy and fiberoptic tracheobronchoscopy in the operating room. In patients with increasing airway distress as the diagnostic work-up proceeds, the insertion of an endotracheal tube over the fiberoptic bronchoscope will restore an airway and document the presence of any tracheal or bronchial injury.

As the resolution of multidetector cervical CT has increased, this diagnostic modality is replacing laryngoscopy and tracheobronchoscopy as the diagnostic modality of choice for patients with subtle injuries to the airway [29].

Zone III

Asymptomatic patients with penetrating wounds in Zone III rarely have an injury to the internal carotid artery.

Table 1 Principles of repair of the carotid artery

Systemic heparinization (100 U/kg) if complex repair (resection with end-to-end anastomosis or interposition graft) or repair at base of skull will be necessary
No intraluminal shunt unless inadequate back-bleeding or prolonged repair at base of skull will be necessary
Interrupted 6–0 polypropylene suture repair in children or in internal carotid artery in all patients
Flushing sequence after verifying back-bleeding is externally, and then into external carotid artery, and, finally, flow is reestablished into internal carotid artery

From [2]. Used with permission

Should "soft" signs of an arterial injury such as a history of bleeding from the wound, proximity of the wound to the internal carotid artery, and/or a nonexpanding hematoma be present, CT-arteriography is performed. A small wall defect (subadventitial or intramural hematoma, intimal defect) might be observed, while a pseudoaneurysm or extravasation at this level would be managed with an endovascular stent or stent graft as mentioned previously.

Wounds of the hypopharynx in Zone III are detected by a physical examination or, sometimes, during laryngoscopy. In the absence of hemorrhage, nonoperative management with antibiotics is appropriate.

Operative management

Positioning/incisions

A rolled sheet is placed transversely under the patient's shoulders, and the head piece of the operating table is dropped posteriorly. This hyperextends the neck of the patient with a penetrating wound who is unlikely to have bony instability of the cervical spine. In addition, the operating table is flexed at its midpoint to significantly elevate the patient's head, neck, and chest.

In the patient who will need exposure of a vascular injury in Zone I, the patient's head is kept straight. If a median sternotomy with an anterior cervical extension is planned, the head is turned away from the side of the extension.

Skin preparation for patients with injuries in Zone I should be from the angle of the mandible down to the umbilicus anteriorly and to the ipsilateral elbow on the side of a possible injury to the subclavian artery. In addition, one lower extremity should be prepared and draped from the umbilicus to toenails to allow for retrieval of the greater saphenous vein from the groin or the medial ankle. Skin preparation for patients with injuries to Zones II or III should be extended superiorly to eye level. This will allow for the admittedly rare need for subluxation of the temporomandibular joint or a vertical osteotomy of the mandible.

Injury to the carotid artery

All patients with "hard" signs of an injury to the carotid artery (external hemorrhage, internal hemorrhage into the trachea or esophagus, rapidly expanding pulsatile hematoma) undergo immediate operation. As noted previously, intubation or a cricothyroidotomy may be indicated in the emergency center prior to formal operation. Loss of the carotid pulse is, of course, a "hard" sign after a penetrating wound. In such a patient without a neurological defect, most centers perform a CT-arteriogram to document the thrombosis and verify that there is no extravasation from the artery superior to the thrombosis. A patient with a thrombosed carotid artery is observed in many centers, and there is no consensus on whether such patients should be anticoagulated. The presence of a palpable thrill/audible bruit is another "hard" sign which is suggestive of a carotid artery—internal jugular vein fistula. Again, a CT-arteriogram is performed to document the presence and location, and a decision is then reached on open repair versus insertion of an endovascular stent graft.

Selected patients with "soft" signs, but with a significant injury to the carotid artery on imaging (extravasation, acute pulsatile pseudoaneurysm, significant disruption of the intima, and/or a significant decrease in blood flow to the brain), undergo urgent repair of the carotid artery, as well.

Patient with a neurological deficit

It has long been recognized that a neurological deficit in a patient with a wound to the carotid artery may also be due to the ingestion of alcohol or illicit drugs or to hypotension. For this reason, all patients with a Glasgow Coma Scale (GCS) $\geq$9 should undergo repair of the injured carotid artery as ligation would not be expected to improve the patient's neurological deficit [4, 6, 30–33]. The patient with a GCS $\leq$8 has an unfavorable outcome 75 % of the time with either revascularization or ligation [34].

Operative repair

Through an oblique cervical incision, proximal and distal arterial control is obtained first before dissection into a

Table 2 Principles of repair of the trachea

No debridement is necessary
One-layer repair with absorbable suture if small or moderate-sized hole
When there is loss of a portion of the anterior or lateral wall, a tracheostomy tube is inserted into the defect. The sternocleidomastoid muscle is then detached inferiorly, mobilized, and sewn in an airtight fashion to the defect after the tracheostomy tube is removed
When there is loss of a portion of the membranous trachea, a three-sided rectangular longitudinal flap of pericardium based superiorly is sewn to the defect to create an airtight seal

From [2]. Used with permission

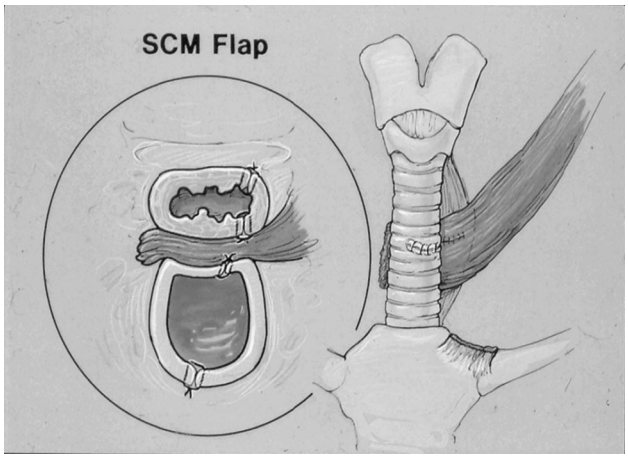


Fig. 6 Sternal head or sternocleidomastoid muscle flaps can be used to buttress a tracheal or esophageal repair or to separate tracheal and esophageal repairs or repair of either from an adjacent repair in the carotid artery (from [36]. Used with permission)

large hematoma. Active external hemorrhage is managed with sterile finger compression on the wound as proximal arterial control is obtained. Distal arterial control is then obtained as the area of back-bleeding from the injury is visualized (Table 1).

Lateral arteriorrhaphy is performed after minimal debridement with interrupted 6–0 polypropylene sutures in all children and in adults with injuries to the internal carotid artery. A patient with an injury large enough to require segmental resection should be heparinized by the occasional vascular trauma surgeon. This theoretically allows for a longer cerebral ischemia time as an end-to-end anastomosis or interposition graft (greater saphenous vein or polytetrafluoroethylene) is performed. The insertion of an intraluminal shunt is limited to patients with segmental resection and inadequate back-bleeding or when the repair will be prolonged because of proximity to the base of the skull. The author has only performed transposition of the external carotid artery to replace the injured proximal internal carotid artery once in his career.

Any repair of the cervical carotid artery should be separated from an adjacent repair of the injured trachea or esophagus with a vascularized pedicle of the sternal head only or the entire detached inferior sternocleidomastoid muscle [35].

Postoperative care involves maintaining a normal blood pressure and oxygenation. In addition, a CT scan of the brain should be performed in patients with a normal preoperative neurological exam, but whose condition deteriorates after carotid repair. The same would be needed in a patient with an abnormal preoperative neurological examination and failure to improve after carotid repair.

In an "ancient", but large clinical review, patients not failing resuscitation (no cardiac arrest or need for emergency center thoracotomy) had a survival of 85 % after operative management of a wound to the carotid artery [30].

Injury to the trachea

No debridement of the injured trachea is performed, and 3–0 interrupted absorbable sutures are used to reapproximate the edges of an anterior or lateral perforation. A large proximal anterior or lateral defect can be sealed by detaching the sternal head of the sternocleidomastoid muscle inferiorly and sewing it in an airtight fashion to the edges of the tracheal defect. A more inferior or larger defect with loss of tissue is generally treated with insertion of an appropriately sized tracheostomy tube until inflammation and edema resolve. Then, formal resection and an end-to-end tracheal repair can be performed (Table 2).

A loss of tissue in the membranous portion of the trachea mandates a median sternotomy and creation of a three-sided longitudinal anterior pericardial flap based superiorly. This flap is then rotated superiorly and sewn to the membranous defect in an airtight fashion.

All complex tracheal repairs or combined tracheoesophageal repairs are buttressed or separated with a vascularized pedicle of the sternal head only or the entire detached sternocleidomastoid muscle as described previously [35] (Fig. 6).

Injury to the esophagus

Minimal debridement of the injured esophagus is performed, and repair is completed using either one

Table 3 Principles of repair of the esophagus

Either one- or two-layer repair with absorbable sutures is acceptable, preferably in a transverse direction
Loss of portion of the wall in Zone II and some patients with a delayed diagnosis of perforation should be treated with a loop esophagostomy over a rod rather than an acute tenuous repair that is likely to dehisce
Combined injuries with the trachea or carotid artery mandate a vascularized muscle buttress/separator such as the sternocleidomastoid muscle

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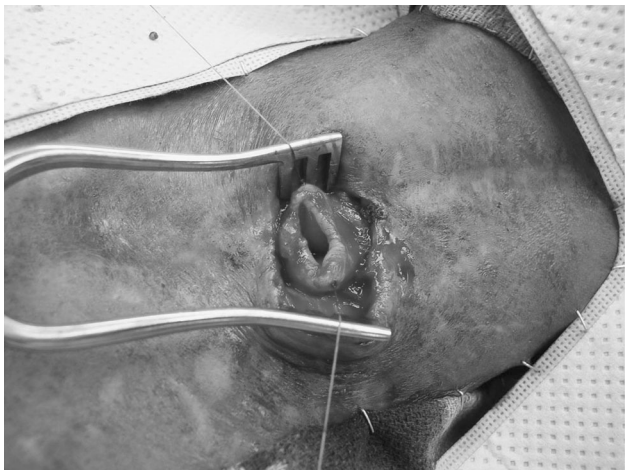


Fig. 7 Closure of a loop cervical esophagostomy in a patient who had an esophagogastrectomy after a distal esophageal repair leaked (from [2]. Used with permission)

(interrupted 3–0 absorbable full-thickness sutures) or two layers (inner continuous 3–0 absorbable suture closure of mucosa, outer interrupted 3–0 absorbable suture closure of muscle). A 5–25 % leak site from such repairs has been reported in the past, so many surgeons place either an open or closed drain adjacent to the repair [36, 37]. This drain should not contact the adjacent common carotid artery at any point because of the risk of erosion [36] (Table 3).

Loss of a portion of the wall of the esophagus, a late diagnosis of a perforation, or a leak of a distal repair is best managed with a lateral blowhole esophagostomy or loop esophagostomy over a red Robinson catheter at the site of the perforation [36, 38]. The goal is to keep the esophagus in continuity to avoid a complex reconstruction in the future. Cervical esophagostomies pull to the posterior midline and shrink over time, so the closure and "drop-back" procedure is often quite easy (Fig. 7).

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