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The management of penetrating neck injury

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Abstract

Penetrating neck injuries are serious as there is a high concentration of vital structures in close proximity to each other in a compressed anatomical area. Penetrating neck injuries can be immediately life threatening due to massive bleeding from vascular structures or due to airway compromise. Injury to the digestive tract in the neck may also result in delayed and potentially life-threatening conditions. The majority (79%) of penetrating neck injuries can be managed conservatively. The clinician caring for such a patient requires a structured and comprehensive approach to managing these injuries. This article will provide a general overview of penetrating neck injuries, including resuscitation, epidemiology, surgical management and the use of appropriate imaging.

Keywords

Penetrating neck injury, neck, trauma, penetrating trauma

Introduction

Penetrating neck injuries (PNIs) are serious injuries as there is a high concentration of vital structures in close proximity to each other in a compressed anatomical area and can be immediately life threatening due to massive bleeding from vascular structures or airway compromise. Injury to the digestive tract in the neck may also result in delayed, and potentially life-threatening, conditions. The clinician caring for such a patient therefore requires a structured and comprehensive approach to managing these injuries and be able to manage competing priorities. The traditional Advanced Trauma Life Support (ATLS®) approach is extremely useful in this scenario as it provides a solid framework for the clinician managing what can be a stressful situation. This best practice review uses the framework provided by ATLS® and covers resuscitation, investigation and management. For convenience the investigation and management of vascular and aero-digestive tract injuries are discussed separately, although they are frequently encountered, considered and managed in tandem.

Epidemiology

PNI constitutes 5–10% of traumatic injuries in adults[1] and has a mortality rate ranging from 10 to 17%,[2,3] almost half of which is secondary to uncontrolled haemorrhage.[4] Although countries like South Africa and other countries in Central and South America have very high rates of interpersonal violence, countries in Europe have reported increasing levels of knife and gun crime over the last decade. A recent study from London reported a dramatic increase in PNIs of over 500% over the last 20 years as a result of increasing rates of interpersonal violence.[5] The majority of PNIs are caused by stab wounds (SWs), with only a minority secondary to gunshot injuries – 16% in London,[5] 11% in South Africa[2] and 8% in Dubai.[4]

Resuscitation

Airway

The airway is the most important structure in the neck and injury can be caused either by a direct wound to the airway or by compression due to swelling. Any obvious

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wounds should be noted as should patient distress, cyanosis, voice changes or stridor. If the patient is talking, assume the airway is patent, but preparation for intubation should be undertaken as deterioration may occur rapidly. Examine for expanding haematoma, tracheal deviation, debris or obstruction in the airway which can be removed with gentle and controlled suction. If there is any doubt about the adequacy of the airway, a definitive airway is required, but it is important to remember that it may be difficult to intubate a patient with a swollen neck and the most experienced clinicians should be available to perform this urgently.

If intubation proves impossible then it will be necessary to proceed to a surgical airway and a surgical cricothyroidotomy is the recommended technique for establishment of an urgent surgical airway. A horizontal incision through the skin and cricothyroid membrane is opened further with a curved haemostat before passing a paediatric endotracheal tube through the cricothyroidotomy into the airway. Confirmation of correct placement is by observation of misting inside the tube, easy ventilation of the patient or the gold standard end tidal CO_2. Surgical airways can be difficult if vascular injury has caused tracheal displacement from surrounding haematoma. Once the situation has been rescued with an urgent cricothyroidotomy it should be replaced by a formal tracheostomy performed in the operating room.

Breathing

Respiratory rate and lung expansion should be looked for, as should any other associated injury, and subcutaneous emphysema or air leak are examined for. High flow oxygen should be administered as required. Penetrating wounds to the root of the neck may result in a pneumothorax or haemothorax and can develop into an immediately life-threatening tension pneumothorax, so tracheal deviation, which is indicative of tension pneumothorax, must be excluded and treated immediately by needle decompression and subsequent insertion of a chest drain if present.

Circulation

Issues with circulation may present with overt external bleeding from a PNI or when the bleeding has stopped due to a tamponade effect.

The patient with overt bleeding. Bleeding from PNIs can be dramatic and catastrophic and needs to be controlled in tandem with attempts to control and secure the airway and the best way to control overt bleeding is by direct pressure; in an open wound direct digital control of bleeding is required but is not a task for inexperienced staff and requires surgical skill. If digital control is effective it should be maintained whilst the patient is expedited into the operating room. Foley catheter balloon tamponade to control bleeding from a neck wound is well described, and if performed well can temporize the bleeding.[6] The largest available Foley catheter that fits into the external wound is inserted and inflated until resistance is felt and the bleeding ceases; the skin is then sutured over the vascular injury to maintain tamponade, after advancing the catheter slightly so as to not rupture the balloon. In this high-pressured scenario, excess traction on the catheter is a real possibility, creating a larger hole and exacerbating the bleeding and must be avoided.

Never blindly apply clamps into the depths of an actively bleeding wound and avoid probing the wound in the emergency department, as this may cause further damage and dislodge any clots. If there is ongoing bleeding which cannot be controlled by direct pressure or Foley catheter then the patient should proceed directly to the operating room. If however, the airway has been controlled and bleeding temporized then imaging may need to be obtained prior to proceeding to the operating room.

The patient with a non-bleeding neck wound. Although the actively bleeding PNI mandates urgent surgery, the situation of a non-bleeding PNI is much more frequently encountered and necessitates a decision from one of three options: mandatory exploration, selective operation in conjunction with mandatory imaging and selective non-operative management in conjunction with selective imaging.[7]

Mandatory exploration: Traditionally, *all* wounds which breeched the platysma muscles were explored[8] which resulted in a high rate of false negative neck exploration and has now been abandoned by most centres.

Mandatory imaging: Some clinicians would image the vascular system and the digestive tract of all patients with PNIs,[9] traditionally by means of formal catheter-directed angiography (CDA) and a contrast swallow or oesophagoscopy, but more recently CT angiography (CTA) has tended to replace formal CDA and the decision to operate was based on the results of these investigations. Exploring the neck without the benefit of a road map of the injury is more challenging and difficult to justify in the modern era where good quality imaging is so freely available.

Selective imaging and selective non-operative management: Mandatory imaging will also result in a high rate of negative investigations and whilst the complication rate of modern imaging is low it is still expensive and a waste of resources, even in more affluent health care systems. For this reason, most authors now advocate

Table 1. Clinical signs of injury in penetrating neck trauma.

	Vascular	Airways	Digestive tract
Hard signs	Exsanguinating haemorrhage Rapidly expanding/pulsatile haematoma Central neurological deficit Bruit or thrill Absent pulse	Visible bubbling injury and airway compromise	Visible injury leaking saliva
Soft signs	Venous ooze Non-expanding/pulsatile haematoma History of significant bleed/hypotension Brachial plexus injury	Dysphonia Haemoptysis Subcutaneous emphysema	Odynophagia/dysphagia Haematemesis Subcutaneous emphysema

Table 2. The zones of the neck.

	Boundaries	Contents at risk
Zone 1	Cricoid process to sternoclavicular notch	• Trachea • Subclavian, innominate and jugular veins • Recurrent laryngeal and vagus nerves • Oesophagus • Proximal section of common carotids • Vertebral and subclavian arteries • Spinal cord and brachial plexus
Zone 2	The angle of mandible to the cricoid process	• Larynx and pharynx • Vagus nerves • Vertebral arteries • Distal section of the common carotids and proximal parts of the internal and external carotid artery • Jugular veins • Spinal cord
Zone 3	Base of skull to angle of mandible	• Extracranial internal carotid and vertebral arteries. • External carotid artery • Jugular veins • Cranial nerves IX–XII • Spinal cord

a policy of selective imaging based on a detailed clinical assessment[10] and only obtain imaging if the patient has a hard or a soft sign of a vascular or aero-digestive tract injury (Table 1). This decision making is intimately related to both the zone of injury in the neck (Table 2) and the mechanism of injury as gunshot wounds (GSWs) are far more destructive than SWs and some authors will routinely image all GSWs to the neck.[11]

Operative management

Before commencing, the operating surgeon must be prepared to extend the incision further up into the neck or down into the mediastinum as the situation demands and to harvest a saphenous vein graft from the groin, and the patient must be draped accordingly. The operative approach can be described according to the zones of the neck, as first described by Monson et al.[12] It is an anatomical classification and is different to the zones used by head and neck surgeons in elective cancer resections.

Obtaining proximal control of injuries to the great vessels at the root of the neck and the superior mediastinum (zone 1) is difficult and may well require a sternotomy; zone 2 injuries are the most accessible to surgical exploration and historically it was common

practice to perform mandatory neck explorations of zone 2 injuries.[8] Due to a high negative exploration rate, a more selective operative management with greater use of CTA is now advocated.[2]

Zone 3 is the most difficult region in which to operate, as it may be difficult to achieve distal control of bleeding vessels where they enter the base of the skull. A number of strategies have been advocated to deal with such injuries including division of the sternocleidomastoid muscle from its insertion at the base of the skull and dislocating the mandible to improve access to the distal internal carotid artery. With modern endovascular techniques it is possible to treat many of these injuries non-operatively. The use of the zones of the neck to guide imaging strategies is now being challenged by the 'no zone' approach,[13] which proposes that the external wound does not correlate with the site or level of the injured structure and so basing an approach on the site of the external wound alone is unhelpful.

Vascular investigations

CDA

CDA was the traditional modality for imaging the vascular structures in the neck[9,10] and in many ways remains the gold standard as it is both highly sensitive and specific and provides excellent quality vascular imaging. It requires cannulation of the femoral artery, however, and has an incidence of catheter-related morbidity but has the advantage of being potentially therapeutic as endovascular surgery becomes more widespread. Active bleeding can be temporized by proximal balloon occlusion as an adjunct to definitive surgery or managed definitively with embolization as in the case of vertebral artery injury or splenic trauma.[14,15] In addition, the ability to deploy endovascular devices may allow for definitive management of aortic arch, proximal carotid and internal carotid and subclavian vessel injuries (Figure 1).[16–18] Purely diagnostic CDA should be reserved for cases when CTA is equivocal or when artefacts such as retained bullets impair interpretation due to metallic scatter.



Figure 1. Catheter-directed angiogram with deployed endovascular stent in the left subclavian artery.

CTA

CTA has largely replaced CDA as an investigative modality of choice to exclude vascular injury (Figure 2)[19,20] with an extremely low false negative rate.[2,9] In one study of 510 PNI patients, 76% underwent CTA and if CTA did not show an injury then it could be safely concluded that there was no injury. There is however a definite risk of a false positive results and this must be borne in mind when planning management of an injury seen on CTA;[11] the use of CTA as a screening modality for asymptomatic patients is probably not justified.[21,22]

Aero-digestive tract investigations

Although in the acute setting the focus is on controlling the airway and vascular injury, it is important to consider a pharyngeal or oesophageal injury. These injuries often present with only subtle clinical findings and symptoms and if not specifically looked for, diagnosed and managed appropriately can be associated with significant morbidity and even mortality due to deep-seated sepsis and mediastinitis. The most common site of oesophageal injury is in the cervical region,[23] but oesophageal injury in PNIs is rare, with the cervical oesophagus only injured in 3–6% of cases.[24,25]

Contrast swallow

This is the traditional modality used to image the pharynx and oesophagus. It is highly sensitive and specific for a surgically significant injury[26] and should be the modality of choice. Water-soluble contrast must be used as leakage of barium may result in pneumonitis or mediastinitis. The patient must be able to co-operate to perform this investigation which limits its usefulness in the obtunded or intubated patient. Contrast swallow studies are less sensitive in detecting hypo-pharyngeal injuries compared to endoscopy.[27]

Endoscopy

Both the digestive tract and the trachea can be assessed by means of endoscopy, which is usually performed in the operating room. It is ideal for patients who cannot undergo contrast studies as they are intubated or

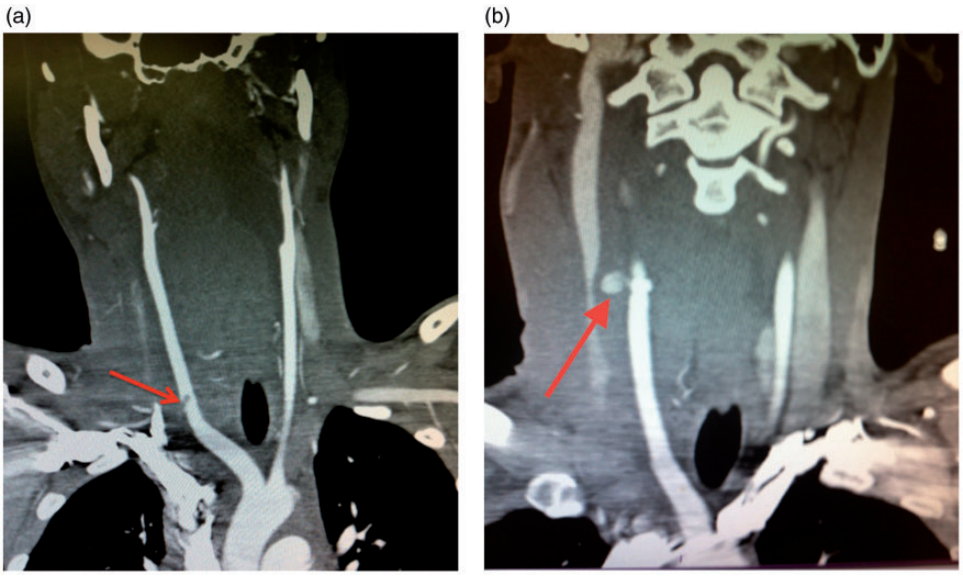


Figure 2. (a) Filling defect in the proximal segment of the right common carotid artery, zone 1 and (b) pseudoaneurysm of the right common carotid artery, zone 2.

otherwise obtunded, but care should be taken so as to avoid exacerbating an undiscovered oesophageal tear.

Management of vascular injury

The management of the vascular injury depends on the vessel which has been injured and the site of the injury. In cases of severe haemorrhagic shock not responding to resuscitation, ligation of major neck veins is preferred. If necessary, the external carotid artery and its branches can be ligated; however, internal carotid injuries should by and large be repaired.[28,29] Endovascular approaches are an alternative.

The key to exploring a patient with a vascular injury in the neck is the same as dealing with a major vascular injury anywhere else and is to obtain proximal and distal control of the bleeding vessel. The steps needed to obtain proximal and distal control will vary depending on the site of the injury. The zones of the neck remain useful when planning a surgical approach to accessing and controlling the injured vessel, but be aware that PNIs may traverse more than one zone, and that the true tract of an injury is often difficult to assess clinically.[13] The site of the external wound is therefore not always a reliable indicator of the location of an injury to the underlying structures which reinforces the benefits of obtaining imaging prior to exploration when the patient is sufficiently haemodynamically stable.

Zone 1

Injuries to vessels in zone 1 of the neck are essentially injuries to the root of the neck and the thoracic inlet. The vessels which may be injured include the first and second parts of the left and right subclavian artery, the innominate artery, the proximal parts of the left or right common carotid artery and occasionally the arch of aorta itself.

The single best incision to provide access to the origin of these vessels in the anterosuperior mediastinum remains a median sternotomy;[30] the brachiocephalic vein usually needs division by suture ligation to open up access to the arch of the aorta and its major branches – once achieved proximal vessel control is usually not difficult. There are advocates of a high third space left thoracotomy who claim this provides access to the left subclavian artery as it runs along the apex of the lung. The major limitation is that the surgeon has very limited access to the superior mediastinum and if the source of bleeding is not the subclavian artery then this approach may be potentially counterproductive.

If the site of the injury has been positively identified as being the second part of the subclavian artery on the left or the right and the patient is not actively bleeding then a more limited approach is acceptable, usually in the form of a supraclavicular incision, extending laterally for approximately 10 cm in length from the sternal notch. Platysma, the clavicular head of the sternocleidomastoid and the omohyoid muscles are divided to expose the fat pad in front the anterior scalene muscle, containing the phrenic nerve which must be preserved. The phrenic nerve crosses the anterior scalene muscle diagonally from lateral to medial and should be gently retracted medially. The subclavian vein is now exposed beneath the scalenus anterior muscle. Access to the subclavian artery requires

division of the anterior scalene muscle and then the pulsation of the second part of the subclavian artery as it emerges slightly above the clavicle is felt. If operating on the left side it is important to be aware of the thoracic duct which enters the confluence of the internal jugular and subclavian vein behind the medial border of the anterior scalene muscle; if this structure is injured it should be ligated.

Where possible, repair of the proximal common carotid arteries should be undertaken to avoid the risk of cerebral infarction associated with ligation of these vessels especially in the hypotensive patient. They may be repaired with a primary lateral repair, end-to-end anastomosis, with the use of an interposition graft such as a reverse saphenous venous graft or a synthetic graft, or a patch angioplasty.[31]

Zone 2

Injuries in zone 2 (Figure 3) are accessible through a formal neck incision along the anterior border of the sternocleidomastoid muscle with extension to the mastoid process (avoiding the hypoglossal nerve) or sternal notch as required. The anterior border of sternocleidomastoid becomes visible after incision through skin and platysma and is retracted laterally and the carotid pulsation will guide the surgeon onto the carotid sheath which contains (from lateral to medial) the internal jugular vein, the vagus nerve and the common carotid artery. To expose the common carotid artery the facial vein, which drains into the internal jugular vein, must be divided and suture ligated. Once the common carotid has been identified it can be followed in a cephalad direction until the bifurcation is reached, identifying and protecting the vagus nerve within the carotid sheath. Carotid artery injuries should almost always be repaired, usually by primary repair or use of an autologous interposition graft; more exotic options such as interposing the internal and external carotid are by and large the stuff of case reports and such complexity should be eschewed in favour or simplicity.



Figure 3. Zone 2 stab wound.

If the patient is truly in extremis, then ligation of internal or common carotid vessels can be performed, but the outcome is variable and depends on both anatomical factors such as the patency of the Circle of Willis and the physiological state of the patient.[32]

Zone 3

This is a difficult region in which to operate, as the facial skeleton obstructs a clear surgical view. A number of approaches have been described some of which are quite exotic and include craniotomy, and manoeuvres to anteriorly displace the mandible. Generally, this is not necessary and access can be gained by dividing sternocleidomastoid off its insertion into the skull and dividing the posterior belly of the digastric muscle and if necessary dividing the styloid process. Sustained traction on the angle of the mandible generally provides sufficient exposure to the internal carotid in this region.

Vertebral artery injuries

Vertebral artery injury has a low mortality rate of only 6.9%[33] and most injuries to the vertebral artery can be dealt with by angiographic embolization.[33,34] If the injured vessel is actively bleeding and exploration is necessary it is important to remember that the proximal portion of the vertebral artery enters the spinal transverse process at the level of C6. It is usually impossible to get access distal to that point. Some authors have described unroofing the artery in this bony canal or blind clipping above and below the injury,[33] but these approaches carry the risk of cervical nerve root damage. A safer option is to ligate the vertebral artery at its origin on the second part of the subclavian and to then occlude the foramen with bone wax.

Endovascular management

The difficulty associated with surgical access to injuries of zones 1 and 3 has led to the expansion of endovascular approaches to injuries in these regions.[35–39]

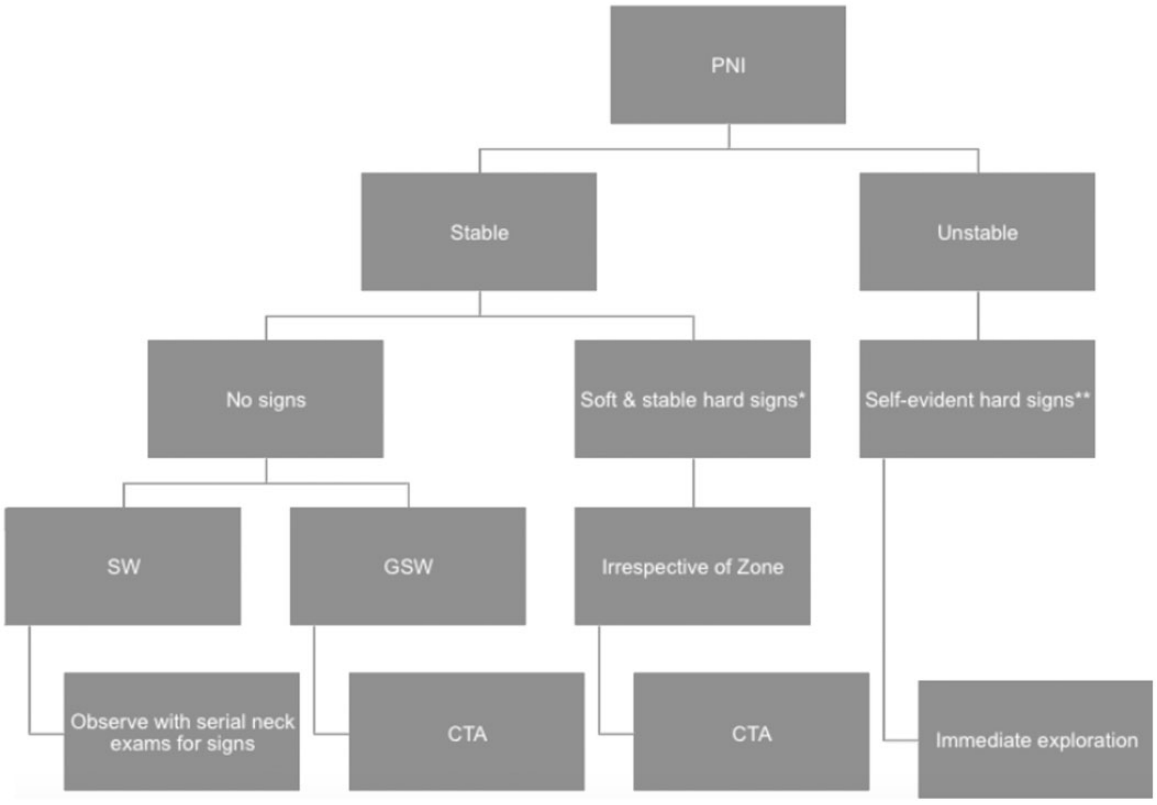


Figure 4. Algorithm for PNIs. CTA: CT angiography; GSW: gunshot wound; SW: stab wound. *Bruit, thrill, central neurological deficits and absent pulse; **Exsanguinating haemorrhage or rapidly expanding neck hematoma.

Endovascular procedures have been well documented in the post-traumatic elective setting to treat pseudoaneurysms and arteriovenous fistulas; however, endovascular approaches are now being used in the emergency setting. Studies have documented the successful endovascular control of vertebral, subclavian and axillary artery injuries in hypotensive patients.[15,33–39] Du toit et al.[16,17] described the endovascular approach to subclavian, axillary and proximal carotid artery injuries, using stent-graft deployment, and have demonstrated excellent long-term follow-up results of this approach in small numbers of patients, with only a single late stent occlusion but no strokes or stent graft-related deaths; others report less blood loss and procedure time using an endovascular approach.[38] Difficult surgical access to the proximal part of the vertebral artery has resulted in angiographic embolization now being the treatment of choice for such injuries.[15] Despite rising popularity, endovascular approaches are still an uncommon intervention in the acute setting, and more studies are required to establish its efficacy.

Aero-digestive tract management

Any patient with gross extravasation of contrast on water-soluble swallow should be repaired urgently. Aero-digestive tract injury should be suspected in zone 1 and 2 wounds in the presence of haematemesis, odynophagia/dysphagia, haemoptysis, dysphonia or surgical emphysema, which may either be palpable or seen in the deep fascial compartments of the neck on CTA.[40] Oesophageal perforations should be managed with minimal debridement and primary repair. Upper thoracic oesophageal perforations are approached by a right thoracotomy and a left thoracotomy approach used for access to the lower third. Lesions at the gastro-oesophageal junction are approached by upper midline laparotomy or a left thoracotomy. A small subgroup of oesophageal injuries may be successfully managed non-operatively provided they have only a contained bleb of extravasation on water-soluble swallow, are recognized within 24 h so mediastinal contamination is minimized and managed appropriately with antibiotics and nasogastric feeding;[41] surgery, however, is still considered the gold standard for the management of the majority of these injuries.

Tracheal injuries greater than one-third of the circumference of the lumen should be repaired.[41] The preferred method is either primary repair or resection with anastomosis. The proximal third of the trachea can be accessed by a low collar incision. A full clamshell incision with a partial upper median sternotomy provides

excellent access to the middle third. Perform a right thoracotomy for access to the distal third of the trachea, the carina and right main bronchus, and a left thoracotomy for access to the left main stem bronchus. Massively destructive tracheal injuries are highly lethal. If there is massive tissue loss the priority is to secure the airway. Complex tracheal reconstruction is highly specialized and beyond the remit of this article. Patients with combined tracheal and oesophageal injuries are at increased risk of trachea-oesophageal fistula (TOF), oesophageal leaks, aspiration pneumonia and mediastinal abscess. In cases of combined injury, the use of a pedicled intercostal muscle flap between the two repairs is mandatory to prevent TOF.[41]

Conclusion

An algorithmic approach to PNIs is useful. The unstable patient with 'self-evident hard signs' of vascular injury or has a threatened airway and is not responding to resuscitation must be expedited to the operating room. If the patient is not in extremis, then detailed clinical examination is important to guide the management strategy. If there are soft signs or 'stable hard signs' or a GSW mechanism of injury then the patient should be imaged as this may determine the surgical approach or facilitate a non-operative approach (Figure 4). The majority of PNIs can be managed conservatively.

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