Trauma Case Reports 32 (2021) 100402

Contents lists available at ScienceDirect

Trauma Case Reports

journal homepage: www.elsevier.com/locate/tcr

Case Report

An unusual case of a penetrating neck injury (PNI) illustrating the use of a "no zone" approach for the management of this injury and a review of the literature

A.P. Joseph [a,*], A. Newey [b], A. Glover [c], W. Mohabbat [d]

[a] Emergency Department and Trauma Service, Royal North Shore Hospital, St Leonards, NSW 2065, Australia
[b] Radiology Department, Royal North Shore Hospital, St Leonards, NSW 2065, Australia
[c] Endocrine Surgical Unit, Royal North Shore Hospital, St Leonards, NSW 2065, Australia
[d] Department of Vascular Surgery, Royal North Shore Hospital, St Leonards, NSW 2056, Australia

ARTICLE INFO

Keywords:
Penetrating neck injury
"No zone" evaluation
Computed tomographic angiography
Evidence-based management

ABSTRACT

We present an unusual case of a young male with a penetrating neck injury (PNI) due to a work-related injury. A metallic foreign body traversed from entry at surgical Zone 2 to Zone 1 in the neck and resulted in a transection of the left thyrocervical trunk at the origin with the left subclavian artery. Computed Tomographic Angiography (CTA) of the aortic arch and major branch vessels demonstrated haemorrhage anterior to the left subclavian artery and left thyrocervical trunk. We describe some of the diagnostic and operative challenges which may occur in these rare and life-threatening injuries. We have also reviewed some of the recent key literature on this topic and have collated the recommendations of the review.

In recent years, there has been a movement away from selective "zone-based" mandatory surgical exploration for Zone 2 injuries, as well as invasive and time-consuming investigations (such as digital subtraction angiography, contrast oesophageal swallow and bronchoscopy) for Zone 1 and 3 injuries due to the high number of negative surgical procedures and investigations. We demonstrate there is now an evidence-based algorithm which demonstrates that a "no zone" approach to the management of these patients is safe and effective. This requires an initial physical examination looking for the presence or absence of "hard", "soft" or "no" physical signs in these patients, and then deciding on subsequent management which would include immediate surgery, CTA of the aortic arch and branches (and subsequent surgical or other management) or observation only.

Our aim in describing this case it to highlight that there is now good evidence-based guidance for the safe and effective management of patients with this infrequent but potentially fatal injury.

A male 20 years of age arrived at the local Major Trauma Service (MTS) by ambulance after working on demolition site removing a tree stump. He had hit a sledgehammer onto an axe head embedded in the stump at head height in an attempt to split the stump and felt sudden pain in the left side of his neck. He thought that a piece of the axe had broken off and hit him. There was minimal blood loss at the scene.

On arrival at the MTS, he was alert and in no distress. Initial examination revealed a pulse rate of 104 bpm and BP 130/95. The

* Corresponding author.
E-mail address: tony.joseph@health.nsw.gov.au (A.P. Joseph).

https://doi.org/10.1016/j.tcr.2021.100402
Accepted 5 February 2021
Available online 9 February 2021

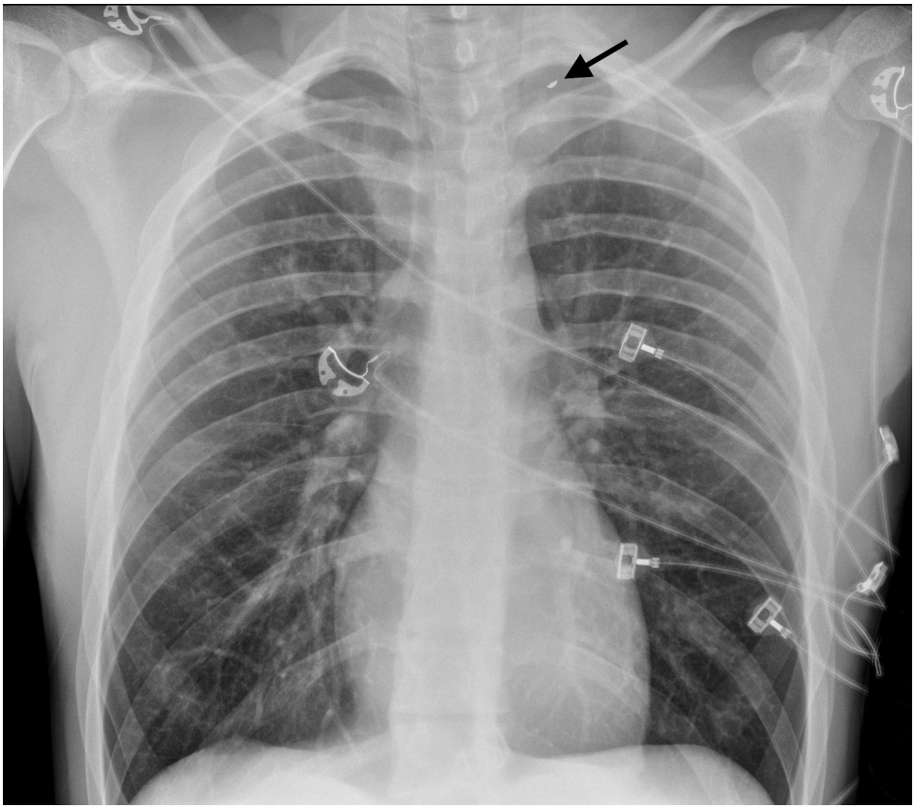

Image 1. CXR.
CXR demonstrates a 5 mm metallic foreign body projected over the left lung apex just superior to the clavicle (black arrow). No pneumothorax seen.

airway was protected and there was a large swelling over the left side of the neck. There was a 4 mm puncture wound with no active bleeding in Zone 2 of the left neck anterior to the clavicular head of the sternocleidomastoid muscle (SCM) approximately 6 cm above the sternoclavicular joint. There was an associated haematoma 7 cm wide × 15 cm long along the SCM muscle which was not pulsatile and there was no crepitus. There was no cervical spine tenderness and a good range of motion of the neck. The chest was clear on auscultation bilaterally and he was moving all limbs equally. There were no other injuries on secondary survey. Chest x-ray showed a 5 mm metallic foreign body at the apex of the left lung with no pneumothorax or haemothorax (Image 1).

A CT Angiogram of the aortic arch and vessels showed a 5 mm metallic foreign body fragment in the left base of the neck anterosuperior to the left subclavian artery and immediately anterior to the left thyrocervical trunk. Active arterial contrast extravasation was seen and thought to be likely arising from the thyrocervical trunk or subclavian artery. The more distal subclavian artery and branches of the thyrocervical trunk, including the inferior thyroid and suprascapular artery, showed normal enhancement. The left vertebral artery was normal (Images 2 and 3).

Surgical management

The patient was transferred to Operating Theatre with both general and vascular surgical teams in attendance for exploration of the left side of neck. At surgery, there was a **transection of the left thyrocervical trunk at the origin on the left subclavian artery** which was repaired after balloon occlusion of the left subclavian artery due to significant bleeding from base of the wound at initial exploration. The thoracic duct was also injured and was repaired.

Surgical exposure and technique

This involved a standard supraclavicular approach to the subclavian artery. The subclavian fat pad was reflected and the scalenus anterior muscle was divided. The subclavian vein was slung with vessel loops inferiorly to expose the subclavian artery posterior to this. There was brisk arterial haemorrhage from the base of the wound which made proximal dissection of the subclavian artery risky and difficult and so a decision was made to use a balloon occlusion technique before further formal open repair on the artery. The artery was exposed to allow control and repair only after the balloon occlusion was in place.

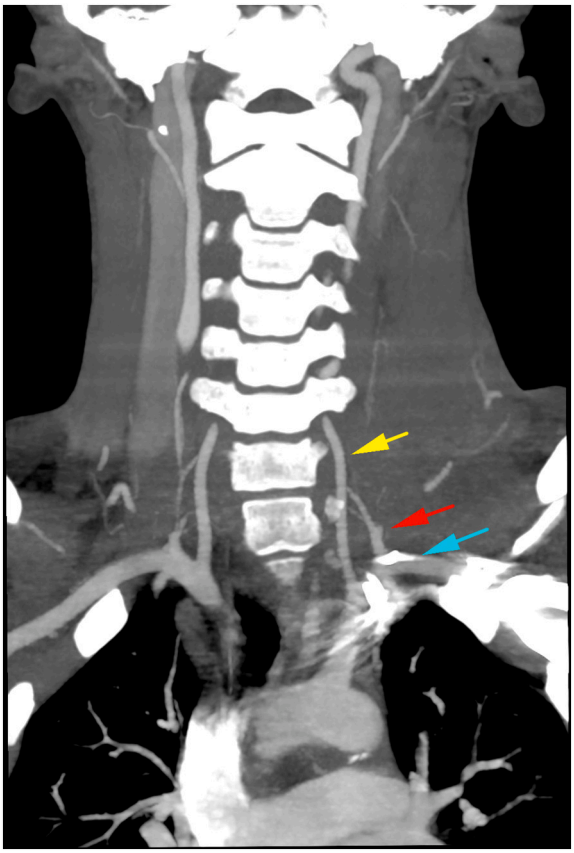

Image 2. Coronal CTA (a).
Coronal MIP CT angiogram demonstrates the metallic foreign body (blue arrow) located immediately anterior to the left thyrocervical trunk (red arrow) with adjacent active contrast extravasation (not shown). Left vertebral artery was normal (yellow arrow).

Balloon Occlusion of the left subclavian artery

The left brachial artery was accessed by micro-puncture under ultrasound guidance and a 5 French sheath was placed. A wire was then passed across the subclavian artery into the aorta. The balloon diameter was chosen to match the native diameter of the subclavian artery to provide complete occlusion to flow. The length of the balloon was short (40 mm) to cover just over the traumatised segment of the vessel. The balloon remained entirely within the subclavian artery and it did not pass across the innominate artery, left common carotid artery or the aortic arch. When the balloon was inflated, the surgical team was able to control the haemorrhage from the left subclavian artery and directly repair the proximal thyrocervical trunk at its origin from the left subclavian artery. The balloon was deflated once formal open exposure of the subclavian- thyrocervical arteries was complete and clamps were placed on the left subclavian artery to stop inflow into the thyrocervical trunk.

The total balloon inflation time was 15 min. Subsequently, the patient developed thrombus in the brachial artery during the balloon inflation period. This was evident by the detection of poor left brachial and radial pulses after repair of the thyrocervical trunk. A left brachial arteriotomy performed, a 4Fr Fogarty arterial catheter was passed up the left subclavian artery and significant thrombus was retrieved followed by good arterial inflow. After haemorrhage control, the patient received a 5000 Unit bolus of intravenous unfractionated heparin (UFH) which was followed by an intravenous infusion of 30,000 units of UFH over 24 h. This was followed by 5000 units UFH$\times$ 3 times per day subcutaneously.

Post-operative progress

On day 2 the patient developed bi-frontal headache, photophobia and fluctuating diplopia on left lateral gaze with a right inferior quadrantanopia. A CT angiogram of the neck and brain did not show an abnormality of the vertebral or internal carotid arteries, however there was a small linear filling defect in the left subclavian artery just distal to the origin of the left vertebral artery possibly representing either a small dissection or intimal disruption associated from the recent vascular repair and intervention. A venous duplex ultrasound showed an acute occlusive thrombus in the proximal left internal jugular vein extending 10 cm into the left neck. An arterial duplex scan showed an area of local dissection on the proximal left subclavian artery just distal to the origin of the left vertebral

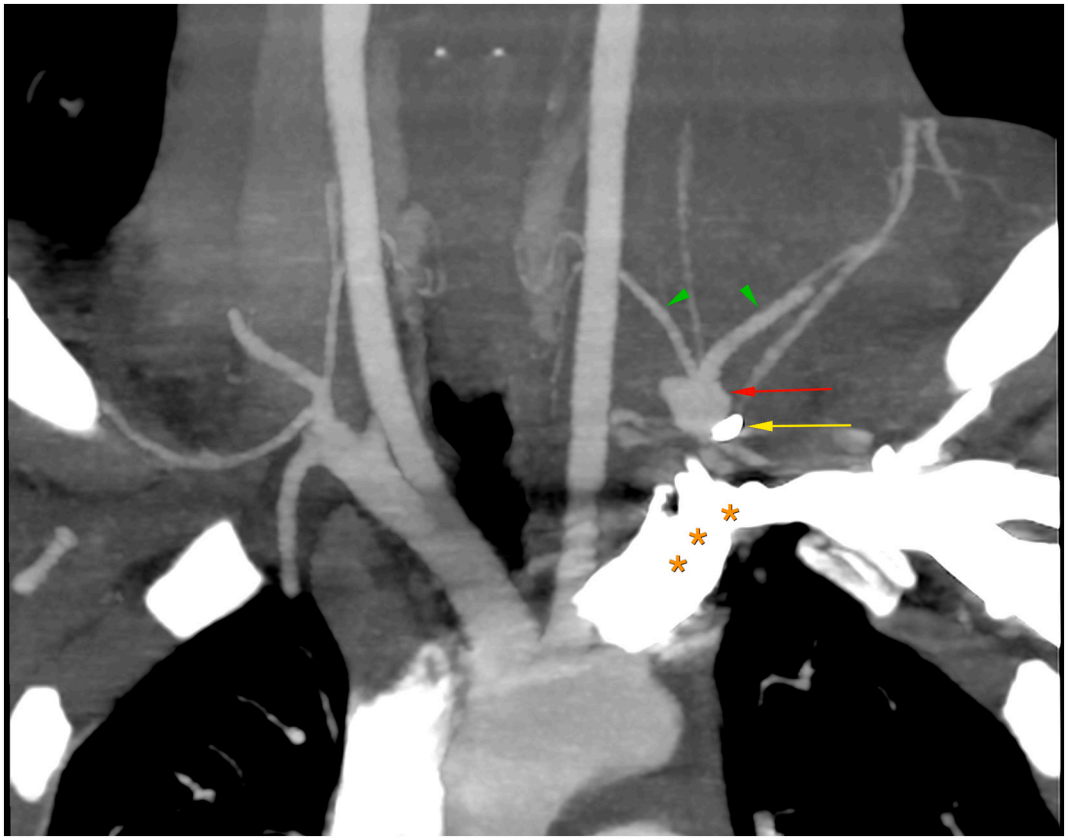

Image 3. Coronal CTA (b).
Coronal MIP CT angiogram demonstrates the metallic foreign body (yellow arrow) located immediately anterior to the thyrocervical trunk. Branches of the thyrocervical trunk (green arrowheads) and active contrast extravasation (red arrow) are shown. Injected intravenous contrast in the left subclavian vein (orange asterisks).

artery.

A MRI brain showed a small acute infarct in the left occipital lobe. Neurology and vascular surgical services were consulted and suggested oral aspirin 100 mg daily and therapeutic anticoagulation for 3 months. Subcutaneous UFH 5000 units three times per day was continued for 5 days followed by a therapeutic dose of enoxaparin 100 mg daily subcutaneously (1.5 mg/kg daily) on day 6 after admission and the aspirin was continued at a dose of 100 mg daily.

Post discharge from hospital

The patient was discharged on day 6 and was reviewed in the general surgical clinic 2 weeks after discharge with the anticoagulation continued at the same dose for each drug. He was reviewed in the vascular surgery clinic at 3 weeks after discharge and was then transitioned to oral Rivaroxaban 20 mg daily to replace the enoxaparin injections. The left subclavian artery dissection had resolved on duplex scanning at 9 weeks post discharge, but the left internal jugular vein thrombus remained visible on venous duplex scan until 12 weeks post discharge. At this time there was complete neurological recovery, and all anticoagulation was ceased. He has remained well and symptom free after that time.

Discussion

Penetrating neck injuries (PNIs) have been previously classified into anatomical Zones 1–3 by Roon and Christensen [1] (Image 4 and Table 1). A laceration of the thyrocervical trunk is unusual due to relative protection by its position deep in the root of the neck in surgical Zone 1, where it lies posterolateral to the internal jugular vein. There have been reports of a pseudoaneurysm of the thyrocervical trunk associated with penetrating injury to the root of the neck in Zone 1 [2]. This injury was also unusual in that the entry site of the metallic foreign body crossed from a Zone 2 entry point to the Zone 1 injury site.

Although PNIs occur relatively infrequently, there is a high case-fatality rate of approximately 10% with the risk of major vascular, airway, neurological or oesophageal injury [3]. Trauma surgeons have previously advocated a “selective” or “zone-based” approach for the management of penetrating neck trauma. This consisted of mandatory surgical exploration for all Zone 2 injuries, which

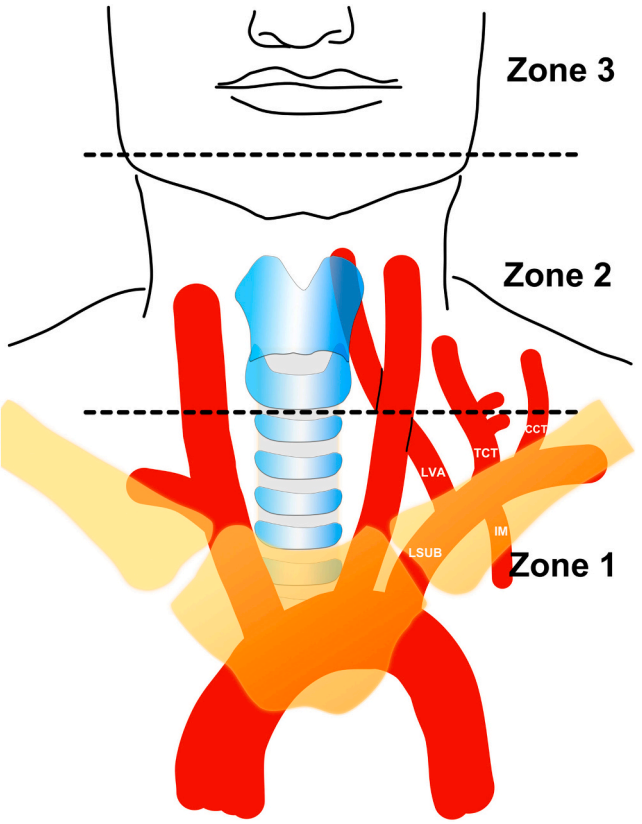

Image 4. Zones of neck and vessels.
Key vessels:
LSUB = left subclavian artery
LVA = left vertebral artery
TCT = thyrocervical trunk
IM = internal mammary artery
CCT = costocervical trunk.

Table 1
Zones of the neck [1].

Zone 1	Sternal notch to cricoid cartilage
Zone 2	Cricoid cartilage to angle of mandible
Zone 3	Angle of mandible to base of skull

Table 2
Hard signs of PNI [6].

Active bleeding or Shock
Expanding or pulsatile haematoma
Bruit or Thrill
Massive subcutaneous emphysema
Air Bubbling from wound
Massive haemoptysis or haematemesis

penetrated the platysma, and digital subtraction angiography (DSA) and/or endoscopy in selected patients with Zones 1 and 3 injuries with clinical signs. This strategy was successful with low numbers of missed injuries and successful non-operative surgical rates up to 66%. However, there have been concerns raised about the relatively high rates of negative exploration rates in stable Zone 2 injuries (13–19%) and poor correlation between the location of the external neck wound and the location of the organ injury [4].

More recently Trauma surgeons have adopted a “no zone” approach to the management of PNIs with

Table 3
Soft signs of PNI [6].

Venous oozing
Non-expanding or non-pulsatile haematoma
Minor haemoptysis
Dysphonia
Dysphagia
Subcutaneous emphysema

a) reliance on "hard" signs of vascular or aero-digestive injury to determine immediate operative management (Table 2) or
b) clinical judgement with the liberal use of CT Angiography (CTA) to guide further radiological or surgical management. This approach has further simplified the management of PNIs with very few missed injuries and low negative exploration rates of 1–2% [3].

CTA has become the investigation of choice for the triage and further management of PNI irrespective of the zone of injury in a stable patient with no indication for immediate surgery. Arterial injuries occur in 10–25% of patients with PNIs and the carotid arteries are injured twice as frequently as the vertebral arteries. Arterial injuries include occlusion, dissection, pseudoaneurysm, active bleeding and arterio-venous fistula.

Venous injuries can also be seen but these are usually managed conservatively. CTA can also diagnose trachea-laryngeal injuries (1–7%) and oesophageal injury (0.9–6.6%) associated with PNIs [5].

In a prospective study of 453 patients with PNI over 31 months, Inaba et al. provided an evidence-based guideline for the management of patients who were classified as having "hard" signs (Table 2), "soft" signs (Table 3) or the absence of clinical signs for vascular or aero-digestive injury on initial assessment [6]. The "hard" signs group (39 or 8.9%) all had immediate surgery and 89.7% had a clinically significant injury requiring operative management. The "no" signs group (189 or 41.7%) were observed clinically for a mean of 2.6 days with no missed injuries. The "soft" signs group (225 or 49.7%) all had a CTA. The most common soft sign was a non-expanding or non-pulsatile haematoma, followed by venous oozing and subcutaneous emphysema. CTA found a total of 28 injuries in 22 patients (22 vascular, 3 oesophageal and 3 tracheal injuries) with a sensitivity of 100% and specificity of 97.5%. There were 2 false positive vascular injuries and 4 nondiagnostic studies due to artefact. All of the above injuries were confirmed by surgery, conventional DSA, bronchoscopy or contrast oesophageal swallow. The authors concluded that physical examination of patients with PNI can safely triage patients to either immediate surgery or observation only. Those patients with "soft" signs can be safely investigated with CTA with a high sensitivity and specificity, and those with negative studies can be observed safely. Equivocal CTA findings due to artefact associated with metallic foreign bodies should be further investigated by conventional DSA, contrast swallow and endoscopy.

This above case illustrates the use of CTA as part of the evaluation process in a young male with "soft" signs due to an unusual penetrating injury, which crossed two surgical zones of the neck, resulting in a life-threatening arterial injury. The CTA showed the trajectory of the missile as it crossed from Zone 2 to Zone 1 in the neck and demonstrated haemorrhage in close association with the transected left thyrocervical trunk.

This diagnostic approach allowed appropriate surgical planning by the general and vascular surgical teams in order to approach and repair both the transected artery and the injured thoracic duct.

The case also illustrates the occurrence of some of the complications and management challenges associated with this injury including arterial dissection as well as both arterial and venous thrombosis.

References

[1] A.J. Roon, N. Christensen, Evaluation and treatment of penetrating cervical injuries, J. Trauma 19 (1979) 391–397.
[2] A. Elkbule, S. Shaikh, J.D. Ehrhardt, et al., Superficial stab wound to Zone 1 of the neck resulting in thyrocervical trunk pseudoaneurysm presenting as a recurrent hemothorax and successfully managed by coil embolisation, Am J Case Rep (2020) 21 (Am J Case Rep 2020; 21: e920196), 10.12659/AJCR.920196.
[3] A.M. Shiroff, S.C. Gale, N.D. Martin, et al., Penetrating neck trauma: a review of management strategies and discussion of the "no zone" approach, Am. Surg. 79 (2013) 23–29.
[4] S. Prichayudh, J. Choadrachata-anun, S. Sriussadaporn, et al., Selective management of penetrating neck injuries using "no zone" approach. Injury, Int. J. Care Injured 46 (2015) 1720–1725.
[5] S.D. Steenburg, D. Leatherwood, Penetrating neck trauma: a review of image-based evaluation and management, Appl. Radiol. (2016) 17–26. https://scholarworks.iupui.edu/bitstream/handle/1805/10916/Steenburg_2016_penetrating.pdf?sequence=1.
[6] K. Inaba, B.C. Branco, J. Menakar, et al., Evaluation of multidetector computed tomography for penetrating neck injury: a prospective multicentre study, Trauma 72 (1) (2012) 576–584.