

**'EVIDENCE DRIVEN' CLINICAL SCENARIO**

## Penetrating Neck Injury in Two Dutch Level 1 Trauma Centres: the Non-Existent Problem

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### WHAT THIS PAPER ADDS

This evidence driven clinical scenario summarises guideline recommendations regarding management of penetrating neck injuries (PNIs) and associated carotid artery injury, for (European) surgeons confronted with this potentially complex problem. When comparing these recommendations to PNI management in two Dutch level 1 trauma centres, it appears that CTA scanning has taken a more prominent role in PNI management than that described in guidelines. Furthermore, to explain clinical decision making, an illustrative case of PNI was added.

**Objectives:** Penetrating neck injuries (PNIs) have a low incidence in European trauma populations. Selective non-operative management of PNI has been suggested as a safe alternative to standard surgical neck exploration, but evidence is lacking. This clinical scenario evaluates institutional PNI management, specifically the associated carotid artery injury, and compares it with current guidelines.

**Methods:** Retrospectively, PNI patients presenting at two Dutch level 1 trauma centres from 2007 to 2015, were identified. International guidelines on PNI management were reviewed and recommendations were assessed in relation to current institutional management, and considering an illustrative case.

**Results:** Two current guidelines on PNI management were reviewed. Both advocate a zone based approach; one recommends a prominent role for computed tomography angiography (CTA) scanning in stable patients, supplemented by endoscopy when indicated. A combined total of 43 PNI patients were identified over a nine year period. Haemodynamically unstable patients and patients with other hard signs (i.e. active bleeding, expanding haematoma, air/saliva leak, massive subcutaneous emphysema) received immediate exploration ( $n = 9$ ). Haemodynamically stable patients and those responding to resuscitation (transient responders) had a CTA scan ( $n = 31$ ). Three asymptomatic patients were treated conservatively, and had an uncomplicated clinical course regarding the PNI. In 10 of 14 patients who received surgical exploration, a significant vascular or aerodigestive injury was found and repaired (71%). All patients treated conservatively after CTA scanning had an uncomplicated clinical course regarding the PNI ( $n = 17$ ). Six patients with penetrating carotid artery injury underwent primary arterial reconstruction, of whom five survived.

**Conclusions:** This clinical scenario evaluates institutional management in two trauma centres for PNI and associated carotid artery injury, and compares it to current guidelines. In comparison with guideline recommendations, CTA scanning and the so called “No zone” approach appears to have assumed a more prominent role in management of PNI.

**Keywords:** Carotid artery injury, Penetrating neck injury, Selective management, Trauma centre

Article history: Received 23 March 2018, Accepted 20 April 2019, Available online 12 July 2019

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<https://doi.org/10.1016/j.ejvs.2019.04.020>

### CLINICAL VIGNETTE

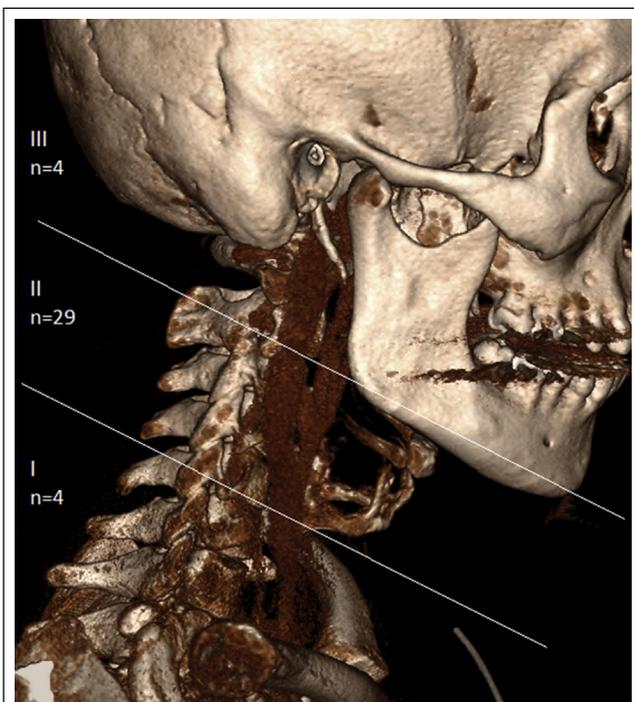
A 34 year old male presented at the emergency department after a wooden foreign body penetrated the neck (above the right proximal clavicle), in close proximity to vascular structures, including the carotid and subclavian arteries. What management strategy for penetrating neck injury

should be pursued, and what is the role of endovascular and reconstructive surgery?

The Netherlands is a low incidence region with regard to penetrating injuries in general, including penetrating neck injuries in particular. This evidence driven clinical scenario summarises international guideline recommendations for the management of penetrating neck injuries (PNIs) and associated carotid artery injury, for the benefit of (European) surgeons who are less often confronted with this potentially complex problem. Current PNI management in two Dutch level 1 trauma centres was compared with these recommendations. An illustrative clinical vignette was added, displaying clinical decision making.

### DETAILED CLINICAL SCENARIO

A 34 year old male presented at the emergency department after sustaining a penetrating injury to the neck, located in zone I (see zones of the neck, Fig. 1). While using a circular saw, a wooden foreign body penetrated the neck region just above the right proximal clavicle (Fig. 2A). At presentation the patient was haemodynamically stable. No active bleeding was visible, and no neurological symptoms were observed. Because of a clinical suspicion of haemothorax/pneumothorax, a chest tube was inserted, evacuating 100 mL of blood and air. As no so called “hard signs” for vascular or aerodigestive injury were observed (Table 1), there was no indication for immediate surgical exploration,



**Figure 1.** Zones of the neck as described by Roon and Christensen.<sup>4</sup> Zone 1, extending from the clavicles and sternum to just below the cricoid cartilage. Zone 2, extending from below the cricoid cartilage to the angle of the mandible. Zone 3, extending from the angle of the mandible up to the skull base. Affected zones of the neck found in this cohort are shown.

and computed tomography angiography (CTA) scanning could be performed to rule out vascular or aerodigestive injury.

CTA scanning of the neck and chest showed that the foreign body reached as far as the spinous process of the first and second thoracic vertebrae, and was in close proximity to vascular structures, including the carotid and subclavian arteries (Fig. 2B). The patient was transferred to the operating room (OR) for surgical exploration by trauma and vascular surgeons. An endovascular approach with angiography of the right subclavian, carotid, and vertebral arteries was performed, showing no contrast extravasation. A catheter and guide wire were left in place for a rapid balloon or covered stent intervention to the subclavian artery. Subclavian and jugular venography was performed, showing compression of the jugular vein caused by the projectile. A catheter was inserted into the jugular vein to acquire distal control (Fig. 2C and D). At this point, as endovascular access (and potential proximal and distal control in the case of bleeding) of the right subclavian artery and the right jugular vein had been secured, the foreign body was removed. Both angiogram and venogram showed no signs of contrast extravasation, visual inspection of the vessels revealed no penetrating injuries. There were no post-operative complications. At one year follow up the patient showed no significant signs of neurological impairment or vascular deficit.

This clinical scenario raises the following questions: what management strategy for PNI should be pursued, and such as in this case, what is the role of reconstructive and endovascular surgery?

The Ethical Committee of the University Medical Centre Utrecht provided a waiver of consent. Informed consent for the use of images was obtained.

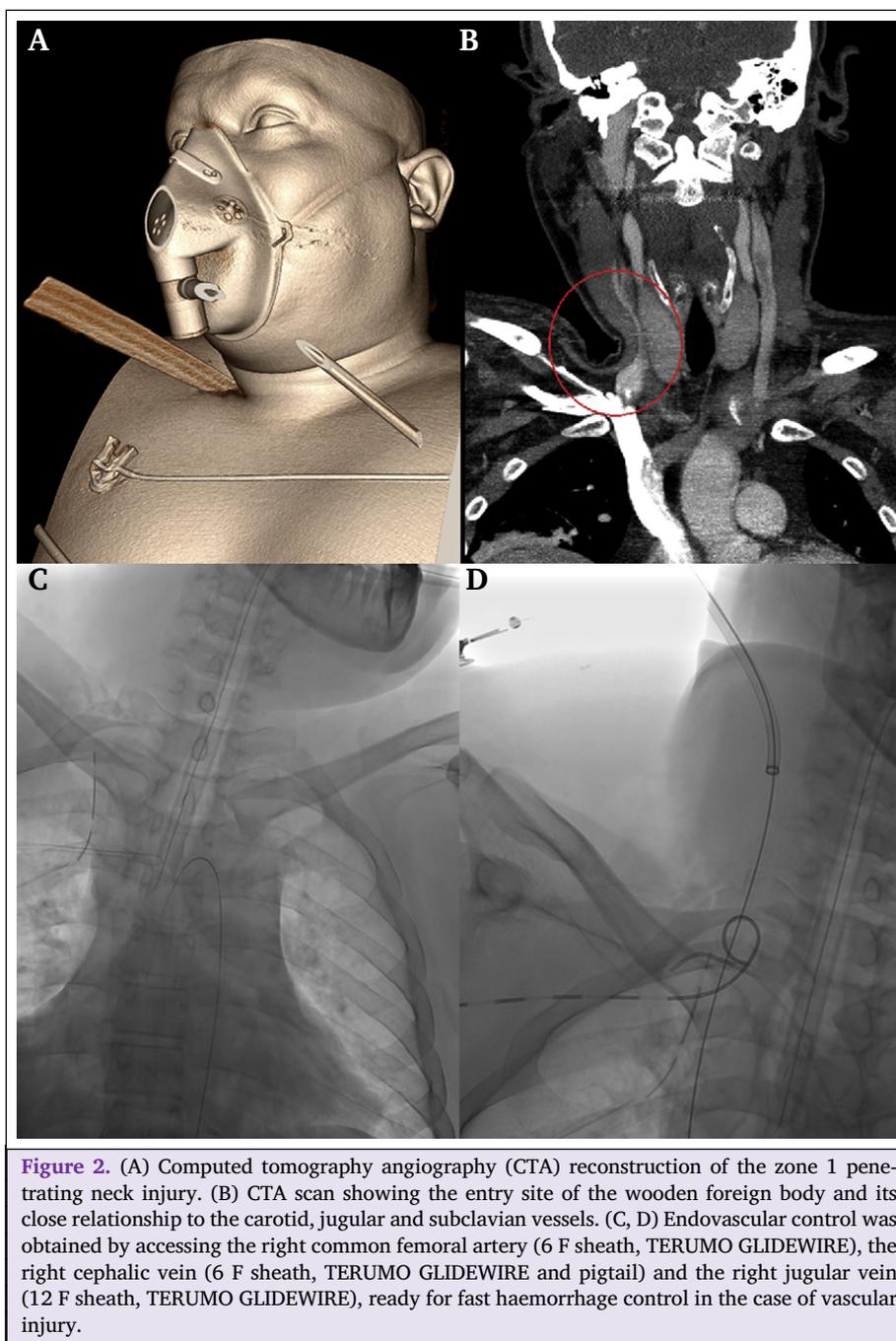
### PENETRATING NECK INJURIES

PNIs are uncommon in the Netherlands, as they are in most European countries. Most available literature and guidelines originate from North America and South Africa where PNI is much more common in urban trauma centres. Treatment of PNI in low incidence countries is based on clinical expertise gained abroad and international guidelines described in the literature.

Penetration of the neck region can cause complex damage to vital vascular, respiratory, digestive, and neurological structures because of the close proximity of these structures to each other.<sup>1,2</sup> Penetrating carotid artery injury may have severe consequences such as airway compromise, cerebral infarction, or in some cases exsanguination, and is associated with a mortality of up to 33%.<sup>3</sup> Treatment is dictated by haemodynamic parameters and so called “hard signs,” symptoms suggestive of severe underlying injuries (Table 1).

### MANAGEMENT DICTATED BY HAEMODYNAMIC STABILITY

Haemodynamically unstable patients (systolic blood pressure  $\leq$  80–100 mmHg, not responding to resuscitation)



**Figure 2.** (A) Computed tomography angiography (CTA) reconstruction of the zone 1 penetrating neck injury. (B) CTA scan showing the entry site of the wooden foreign body and its close relationship to the carotid, jugular and subclavian vessels. (C, D) Endovascular control was obtained by accessing the right common femoral artery (6 F sheath, TERUMO GLIDEWIRE), the right cephalic vein (6 F sheath, TERUMO GLIDEWIRE and pigtail) and the right jugular vein (12 F sheath, TERUMO GLIDEWIRE), ready for fast haemorrhage control in the case of vascular injury.

with PNI associated arterial injury require immediate surgical intervention to achieve proximal and distal control. However, achieving open control in the cranial or caudal region of the neck can be challenging, and may require sternotomy or mandibular dislocation to achieve proximal or distal control, respectively (making endovascular interventions more beneficial). For this reason, the neck is traditionally divided into three zones as described by Roon et al.<sup>4</sup> The structures that are at risk of injury differ per zone and the choice of treatment might be zone dependent.

Mandatory surgical exploration for all patients with PNI was the standard of care for many years.<sup>5–7</sup> Because of the high negative exploration rates and high costs of mandatory exploration,<sup>8–11</sup> selective non-operative management

(SNOM) has become the established practice in most centres.<sup>12–15</sup> SNOM implies that all haemodynamically stable patients receive a thorough physical examination and adequate diagnostic investigations such as angiography (or CTA scanning), endoscopy, and bronchoscopy according to signs, symptoms, mechanism, and zone of injury. According to this approach, haemodynamically stable symptomatic zone II patients should receive mandatory neck exploration and zone I and III PNI patients should receive invasive diagnostics (e.g. angiography or endoscopy) instead of mandatory neck exploration. However, recent literature suggests that dividing the neck into the 1970s anatomical zones has its limitations. The correlation between the external (skin) defect and the internal injuries seems to be

**Table 1. Hard signs on physical examination that justify immediate surgical exploration without further diagnostic investigations, according to the literature<sup>20,21</sup>**

Organ system	Physical examination
Vascular	Expanding/pulsating haematoma Active bleeding Haemodynamic instability (not responding to resuscitation) Pulse deficit Bruit or thrill Airway obstruction
Digestive (pharynx/esophagus)	Haematemesis Saliva leak from wound Subcutaneous emphysema
Respiratory (larynx/trachea/bronchus)	Respiratory distress Air leak from wound Tension pneumothorax Subcutaneous emphysema

poor, and in the case of multiple injuries to different zones, this strategy causes a diagnostic dilemma.<sup>16–18</sup>

Because of these disadvantages and as a result of technological advancements, the evaluation of haemodynamically stable patients has recently changed from the classical, zone based approach, to the so called “No zone” approach.<sup>17,18</sup> This management strategy that is independent of the zone of injury, indicates CTA scanning for all (symptomatic) haemodynamically stable patients with platysma muscle breach (in the absence of hard signs), and based on CT scan findings, operative treatment if deemed necessary. If CTA scanning is negative for underlying injuries, the patient can be observed and treated conservatively. If aerodigestive symptoms are present, or CTA scan findings raise the suspicion for aerodigestive injury (e.g. subcutaneous emphysema) endoscopy can be performed.<sup>14,15</sup> If CTA scanning is negative for significant underlying injuries, the patient is observed and treated conservatively.

Furthermore, thanks to the technical innovation of endovascular procedures over recent years and the close interaction between trauma and vascular surgeons, hybrid techniques are used more often.<sup>19</sup>

## GUIDELINES

In total, two current international guidelines on PNI management were selected and reviewed, as both were published by surgical associations and labelled as a guideline. Originating from high incidence areas, the Western Trauma Association (WTA) and the Eastern Association for the Surgery of Trauma (EAST) published guidelines in the years 2013 and 2008, respectively.<sup>20,21</sup> Most important recommendations were summarised.

The WTA guideline dictates that patients with zone I or III PNI without hard signs, and with a clinical suspicion of underlying injuries, should receive CTA scanning and can be treated according to the findings. In the case of asymptomatic zone II PNI (in the absence of hard signs), patients should receive CTA scanning, while in the case of

symptomatic Zone II, PNI immediate surgical exploration is mandatory. Furthermore, the WTA guideline advocates endovascular treatment, using covered stents, for treatment of arterial injuries in zones 1 and 3. In the case of penetrating injury of the common or internal carotid artery, primary repair is preferred to ligation, irrespective of any pre-operative focal neurological abnormalities.<sup>20</sup>

The EAST guideline dictates that for haemodynamically stable patients, SNOM is equally justified and safe compared with mandatory exploration in zone II injuries, and therefore SNOM should be performed. Furthermore, it dictates that CTA scanning can be used in place of arteriography to rule out arterial injuries in the case of zone II injury. For carotid artery injury it states that, except for minimal intimal irregularities or small pseudoaneurysms (without neurological deficits), arterial reconstruction should be performed, even when severe neurological deficits are present.<sup>21</sup>

Both international guidelines appear to advocate a zone based approach. In contrast to the EAST guideline, the WTA guideline advocates a more liberal use of CTA scanning instead of more invasive diagnostics (e.g. bronchoscopy, endoscopy). Symptomatic zone II PNI patients (both hard signs as well as other symptoms), according to the WTA guideline, should receive mandatory neck exploration. By contrast, the EAST guideline dictates that SNOM might be a safe alternative in zone II PNI patients (in the absence of hard signs).

## DESCRIPTION OF COHORT SERIES IN TWO DUTCH LEVEL 1 TRAUMA CENTRES

Retrospectively, adult patients ( $\geq 18$  years) with PNI admitted to the University Medical Centre (located in Utrecht) and to Elisabeth-TweeSteden hospital (located in Tilburg), in the period from January 2007 till December 2015, were identified and analysed. Both trauma centres provide 24/7 emergency surgical care for trauma and vascular surgery, and have endovascular services available. All patients were initially managed using the Advanced

Trauma Life Support (ATLS) guidelines, and treated by the trauma surgeon on call.

In both hospitals, policy dictates that haemodynamically unstable patients (not responding to resuscitation) and patients with hard signs of a vascular or aerodigestive injury, as described in Table 1, were immediately transported to the OR for exploration and operative treatment.

Haemodynamically stable patients received CTA scanning, irrespective of the zone of injury. The CTA scanning took place in close proximity to (but not within) the trauma resuscitation bay. Depending on the vascular and aerodigestive CTA scan findings, and the signs and symptoms present on physical examination, attending vascular surgeon consultation and operative treatment followed if deemed necessary. In the case of injury to zone I or III, endovascular treatment (using hybrid techniques) was considered. Based on the CTA scan findings (e.g. subcutaneous emphysema without visible perforation) and physical examination findings, endoscopy was considered.

Penetrating neck injury was defined as trauma that penetrates the skin of the neck, with a clinical suspicion of platysma breach. In contrast to the normal definition, requiring definite breach of the platysma, this was done to rule out missing cases. Patients that suffered a combined blunt/penetrating trauma mechanism and had skin penetration were included, whereas those with isolated blunt injury and partially decapitating injuries were excluded. Therapeutic neck exploration was defined as surgical exploration at which a significant vascular or aerodigestive injury was found and repaired.

Vascular injuries to smaller arteries and veins in the neck region, for example the thyroid artery, were defined as other vascular injuries. Airway distress was defined as caused by an expanding haematoma or internal haemorrhage, blunt tracheal injuries as well as that caused by a reduced level of consciousness. Patients were noted as having a pneumothorax if it was caused by an external penetrating object, not by other causes. If the haemodynamic situation was not noted in the patients' clinical records, this was based on vital parameters. The zone of injury

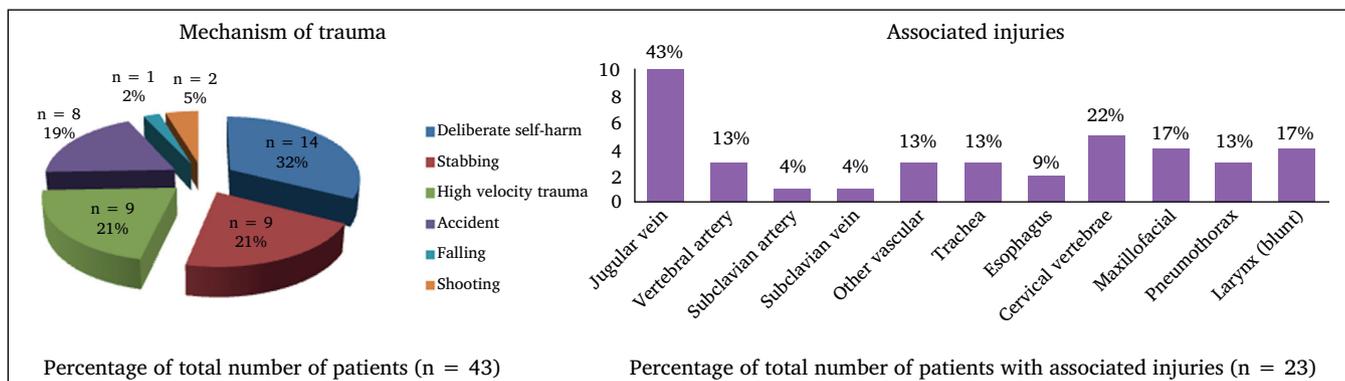
was determined during consultant meetings based on a CTA scan reconstruction and the description of the injury and the underlying damaged structures, if it was not noted in the patient records.

### PENETRATING NECK INJURY PATIENTS

A total of 53 patients with PNIs were identified in the nine year period, combining both hospital populations. Of these, 43 patients met the inclusion criteria. There were 34 men (79%) and nine women with a median (interquartile range) age of 40 years (31–53 years). The predominant mechanism of trauma was deliberate self harm using knives in 14 of 43 patients (33%) (Fig. 3, left). In 29 patients the injury occurred in zone 2, making this the most affected zone (67%). The median injury severity score (ISS) of all patients was 17 (5–24), and 14 patients were haemodynamically unstable at presentation (33%). Surgical exploration was performed in 23 patients (54%). The median hospital stay in days, including intensive care and psychiatric consultation, was six days (2–14) (Table 2).

Seventeen patients had sustained vascular injury as a result of PNI (40%). In seven patients the carotid artery was injured, of whom three suffered from cerebral infarction as a result (Table 3). One patient did not have a visible defect during surgical exploration. Of the six penetrating carotid artery injuries, five were repaired by primary reconstruction of the defect and in one patient an end to end anastomosis was created because of a transection of both the internal and external carotid arteries. Jugular vein injury (either external or internal) was the most common vascular injury, found in 10 patients (23%), of whom one had a laceration on both sides. All three patients suffering from vertebral artery injury acquired this from a combined penetrating/blunt mechanism, in one patient the vertebral artery was torn from the subclavian artery.

Associated injuries, carotid artery injury excluded, were found in 23 of 43 patients (53%) (Fig. 3, right). Penetrating esophageal injuries were found in two of 23 patients (9%), penetrating tracheal injuries were found in three patients



**Figure 3.** (Left) Pie chart showing the mechanism of trauma of all patients. High velocity trauma associated penetrating neck injury (PNI) was in most cases caused by glass, metal, and other debris during road crashes. (Right) Patients found to have associated injuries in the cervical region; the cumulative percentage does not represent all patients with associated injuries (n = 23) because some patients had multiple injuries as a result of the PNI.

**Table 2. Patient characteristics, surgical intervention, and outcome**

Overall group	n = 43
Age, y	40 (31–53)
Male	34 (79)
ISS	17 (5–24)
Airway distress	11 (26)
Haemodynamically unstable	14 (33)
Systolic blood pressure $\leq 90$ mmHg	8 (19)
Pulse rate, bpm	100 (80–110)
Serum Hb, mmol/L	8.2 (7.3–9.1)
Combined penetrating/blunt mechanism	4 (9)
Zone of injury	
Zone 1	4 (9)
Zone 2	29 (67)
Zone 3	4 (9)
Surgical exploration	23 (54)
Carotid artery injury	7 (16)
CVA	3 (7)
Death	3 (7)
Hospital stay, days	6 (2–14)

Data are presented as median (interquartile range (IQR): 25th–75th percentile) or number (%). Zone of injury could not be accurately determined in six patients. CVA = cerebrovascular accident; Hb = haemoglobin; ISS = injury severity score.

(13%). Three patients had a pneumo/haematothorax (13%), all as a result of a zone 1 injury. Other associated injuries such as cervical vertebrae, maxillofacial, and blunt laryngeal injuries were in most cases caused by combined penetrating/blunt mechanisms.

Three patients died as a result of the injuries sustained (7%). Of these, one patient died because of exsanguination and another because of cerebral infarction and cerebral herniation, both caused by carotid artery injury. The third patient died from a diffuse axonal injury after a high

velocity crash. Two patients suffered from cerebral infarction and survived (Table 3).

### INSTITUTIONAL PENETRATING NECK INJURY MANAGEMENT

Based on the medical records of 41 of the 43 patients, placing them in five groups, a management algorithm for the Dutch sites could be constructed to compare management at the study institutions with that described in literature (Fig. 4). Two patients were excluded from this algorithm because both were initially haemodynamically unstable as a result of traumatic abdominal/thoracic injuries. Their PNIs were not surgically explored and delayed CTA scanning showed no significant injuries. They both had an uncomplicated clinical course with regard to the PNI.

In group A, containing three patients who were haemodynamically stable at presentation, two patients were immediately transported to the OR for surgical exploration based on hard signs of aerodigestive injury and in one case because surgical exploration was mandatory because of wound characteristics. Two had penetrating tracheal injuries, of whom one also had a penetrating esophageal injury. In group B, containing three patients who were haemodynamically stable and treated conservatively, two patients had no platysma breach. In one case, based on wound characteristics in an asymptomatic patient, it was decided to perform local wound care and monitor the patient rather than performing additional diagnostic investigations. No vascular or aerodigestive injuries were found. In group C, containing 14 haemodynamically stable patients who received surgical exploration with a CTA scan prior to exploration, 10 patients received therapeutic neck exploration (71%). Three patients suffered from penetrating carotid artery injury (21%), of whom one also had a penetrating esophageal injury and one a penetrating tracheal

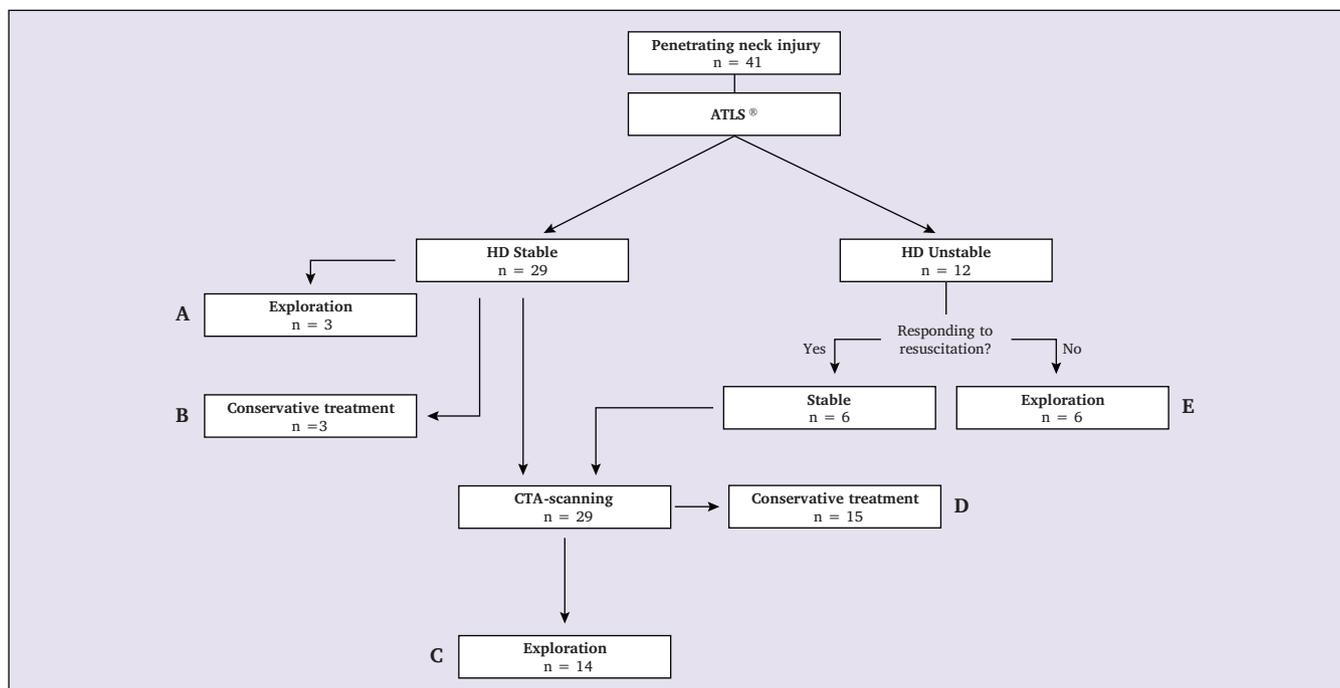
**Table 3. Demographics, treatment, and outcome of patients with carotid artery injury**

Gender	Age	ISS	Mechanism	SBP (mmHg)	Neurology		Injury	Operative treatment	CVA	Outcome
					(Pre-op)	(Post-op)				
Male	44	16	Stabbing	>90	Horner	Right hemiparesis	Penetration ICA	Primary reconstruction	Yes	Alive
Female <sup>a</sup>	54	29	DSH	>90	Coma	–	Laceration CCA <sup>a</sup>	Clamping	No	Dead
Male	26	17	Accident	<90	Coma	Nil	Transection ICA + ECA	Primary reconstruction	No	Alive
Male	19	33	DSH	>90	Horner	Horner	Laceration CCA	Primary reconstruction	No	Alive
Male	20	16	Accident	90	Decreased level of consciousness	Nil	Laceration CCA	Primary reconstruction	No	Alive
Female	44	25	DSH	>90	Left hemiparesis	Left hemiparesis	Laceration CCA	Primary reconstruction	Yes	Alive
Male	33	25	Accident	>90	Decreased level of consciousness	Coma	Occlusion CCA <sup>b</sup>	None	Yes	Dead

CCA = common carotid artery; CVA = cerebrovascular accident; DSH = deliberate self harm; ECA = external carotid artery; ICA = internal carotid artery; ISS = injury severity score; SBP = systolic blood pressure.

<sup>a</sup> Death due to exsanguination during surgery.

<sup>b</sup> No (external) defect of the carotid artery was visible during exploration.



**Figure 4.** Algorithm for management of penetrating neck injury in the Dutch situation, based on 41 patients. Five groups of patients are shown (marked A, B, C, D and E), each one with different management and underlying injuries. Patients treated conservatively were in some cases treated surgically for other injuries (not vascular/aerodigestive) or received additional diagnostic investigations (endoscopy/bronchoscopy). ATLS = Advanced Trauma Life Support; CTA = computed tomography angiography; HD = haemodynamically.

injury. Five patients had a jugular vein injury (36%). One patient suffered from combined blunt/penetrating trauma that tore the vertebral artery from the subclavian artery. One patient required exploration and treatment of a smaller venous injury in the neck that was not further specified. In group D, containing 15 haemodynamically stable patients who were treated conservatively after CTA scanning, all patients had an uncomplicated clinical course. In group E, containing six haemodynamically unstable patients who received immediate surgical exploration, all had a therapeutic neck exploration. Four of these suffered from carotid artery injury, of whom three also had jugular vein injuries and one had a subclavian vein injury.

Based on the algorithm, patients who received surgical exploration based on clinical assessment and CTA scan findings, underwent a therapeutic exploration in 71% of cases. Furthermore, patients who were treated conservatively based on CTA scan findings and clinical assessment, had an uncomplicated course.<sup>20,21</sup>

The present experience shows how selective management of patients with PNI using the “No zone” approach is a successful strategy in two European centres with low PNI incidence. CTA scanning has taken a more prominent role in the institutional management of PNI, in comparison to WTA and EAST guideline recommendations.

#### INSTITUTIONAL CAROTID ARTERY INJURY MANAGEMENT

In the study centres, six patients were treated by primary reconstruction of a carotid artery defect, irrespective of any pre-operative neurological deficits. Of these, five survived.

These results of penetrating carotid artery injury treatment are in accordance with the recommendations in the described guidelines.<sup>20,21</sup> The WTA guideline describes how endovascular procedures (embolisation/stenting) could be beneficial in (inaccessible) zone I and III injuries.<sup>20</sup> Looking back at the clinical vignette, endovascular procedures were beneficial in the difficult to explore zone I PNI, by preventing further invasive surgical exploration to acquire proximal and distal vascular control in the neck and thoracic outlet region. Although a zone based approach has multiple disadvantages, the use of endovascular techniques in zone I and III PNIs because of difficult exposure and vascular control could be considered an advantage to the zone based approach.

#### LIMITATIONS

As this is a retrospective study with a relatively small number of patients, it is necessary to use caution in extrapolating findings to the clinical field. The retrospective nature of the study may have led to missed PNIs. In particular, patients suspected of platysma breach but without actual breach might be underrepresented as they were possibly not classified as PNI patients. This may have led to different study population characteristics.

#### SUMMARY

Penetrating neck injury and associated carotid artery injury is rare in Dutch trauma centres, even in level 1 trauma centres. In most cases PNIs were caused by stabbing, including deliberate self harm (33% of patients). Possibly

because of strict firearms legislation in the Netherlands, PNI as a result of gunshot wounds is very uncommon. A more prominent role of CTA scanning in the selective non-operative management of PNI, the so called “No zone” approach, appears to have safely found its way in two Dutch level 1 trauma centres, deviating from the more zone based approach recommended in international guidelines. This non-invasive imaging screening reduces the number of unnecessary neck explorations performed, and therefore increases the percentage of therapeutic neck explorations and reduces the use of invasive diagnostics. Physicians who are confronted with PNIs could potentially base their decision to either surgically explore PNI or treat it conservatively more on CTA findings and clinical assessment, than on invasive diagnostic modalities, depending on haemodynamic stability. Furthermore, institutional treatment of penetrating carotid artery injury was performed in accordance with international guidelines.

#### ACKNOWLEDGEMENTS

1. Trauma database, University Medical Centre Utrecht, Utrecht, The Netherlands.
2. Trauma database, Elisabeth TweeSteden Hospital, Tilburg, The Netherlands.

#### CONFLICT OF INTEREST

None.

#### FUNDING

None.

#### APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejvs.2019.04.020>.

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