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An audit of penetrating neck injuries in a South African trauma service

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ABSTRACT

Introduction: This study reviews and validates the practice of selective non-operative management (SNOM) of penetrating neck injury (PNI) in a South African trauma service and reviews the impact new imaging modalities have had on the management of this injury.
Methodology: This study was performed within the Pietermaritzburg Metropolitan Trauma Service, in the city of Pietermaritzburg, Kwazulu-Natal, South Africa. A prospectively maintained trauma registry was retrospectively interrogated. All patients with PNI treated over a 46-month period were included within the study.
Results: A total of 510 patients were included in the study. There were 452 stab wounds (SW) and 58 gunshot wounds (GSW). A total of 202 (40%) patients sustained isolated PNI, the remaining 308 (60%) patients sustained trauma to at least one additional anatomical region. An airway injury was identified in 29 (6%) patients; a pharyngo-oesophageal injury in 41 (8%) patients and a vascular injury in 86 (17%) patients. Associated injuries included three penetrating cardiac injuries (PCI) and 146 patients with haemo-pneumothoraces. Of the total cohort, 387 patients (76%) underwent CT Angiography (CTA), of which 70 (18%) demonstrated a vascular injury. Formal catheter directed angiogram (CDA) was performed on 16 patients with positive CTA but confirmed injury in only half of these patients. Of 212 patients (42%) who underwent water-soluble contrast swallow (WS-swallow), an injury was demonstrated in 29 (14%) cases. A total of 401 (79%) patients were successfully managed conservatively for PNI and 109 (21%) surgically or by endovascular intervention. Only five (1.2%) patients failed a trial of SNOM and required surgery. The in-hospital mortality rate was 2%. No deaths could be attributed to a failure of SNOM.
Conclusion: SNOM of PNI is a safe and appropriate management strategy. The conservative management of isolated pharyngeal injuries is well supported by our findings but the role of conservative treatment of oesophageal injuries needs to be further defined. The SNOM of small non-destructive upper airway injuries seems to be a safe strategy, while destructive airway injuries require formal repair. Imaging merely for proximity, is associated with a low yield. CTA has a significant false positive rate and good clinical assessment remains the cornerstone of management.

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Introduction

Mandatory neck exploration for penetrating neck injuries (PNI), leads to a high rate of negative exploration and selective non-operative management (SNOM) of PNI has long been established as a management philosophy in South Africa [1–9]. Most of the original work documenting the applicability of SNOM to PNI dates from the era prior to the advent of new imaging technologies such as CT angiography (CTA) and endovascular surgery. On-going audit is essential to help us contextualize these new modalities and to ensure that they are integrated positively into our existing management algorithms in a way that adds value rather than merely complicates clinical scenarios. There are also subsets of injuries particularly those of the aero-digestive tract, in which the optimal management strategies still remain controversial [10,11, 17–20]. This retrospective review of a prospectively maintained electronic registry and medical record system was undertaken to review the current spectrum and burden of the problem and to review the outcomes of our management strategy in light of the advent of newer technologies. It was also hoped that with the new powerful method of capturing clinical data we would be able to analyse the controversial subsets of injuries in more detail.

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Methodology

The Pietermaritzburg Metropolitan Trauma Service (PMTS) maintains a prospective digital trauma registry, which captures data at our institutions. Ethics approval to maintain the registry has been obtained from the Biomedical Research Ethics Committee (BCA221/13 BREC) of the University of KwaZulu-Natal and from the Research Unit of the Department of Health [12]. Patients with PNI treated from January 2011 to November 2014 were included in the study and data pertaining to the following criteria were collected and reviewed: demographics and injury severity score, mechanism of injury, anatomical site of wounds, special investigations, method of management, anatomical injuries and outcome. Furthermore the number of fatalities from PNI captured and recorded at the state mortuary for the same period was retrieved. Data were exported into Microsoft Excel and analysed using standard statistical tests. Student's *t*-test was used for numerical data and Pearson's Chi-square test was used for categorical data.

Management of PNI

All neck wounds are classified as either posterior to the posterior border of the sternocleidomastoid muscle, or anterior to the posterior border of the muscle [2,3]. Anterior wounds are subclassified according to zone as described by Roon and Christensen [3]. All non-responders and transient responders to resuscitation are subjected to urgent operative exploration.

All responders and stable patients are examined clinically and selectively investigated. Antibiotics are only administered if a digestive tract injury is suspected or confirmed and all patients are observed in hospital for 48 h prior to discharge. Indications for vascular imaging include hard signs of vascular injury such as controlled haemorrhage, pulsatile hematomas, bruits, thrills, cerebral ischemia or pulse discrepancy, or soft signs like small hematomas, a history of severe bleeding or hypotension or focal neurological deficits. With the increased access to CTA proximity alone has increasingly become an indication for investigation in our institutions. Aero-digestive tract injury is suspected if odynophagia, surgical emphysema, haematamesis, haemoptysis or an active, blowing wound is present. CTA is the first line of imaging to exclude a vascular injury. Formal catheter directed angiography (CDA) is reserved for equivocal CTA findings, or where artifacts compromise CTA interpretation. CDA may also be used with therapeutic intent. Water-soluble contrast swallow (WS-swallow) is the investigation of choice to exclude a digestive tract injury. Oesophagoscopy is reserved for select cases or where a swallow cannot be performed for logistical reasons. Rigid or flexible bronchoscopy is used selectively for suspected tracheal injuries.

We explore and repair almost all oesophageal injuries but manage pharyngeal injuries conservatively [10]. Patients with small, contained oesophageal injuries where the contrast on WS-swallow does not track downwards into the mediastinum may be candidates for conservative management [11,17]. Conservative management consist of intravenous antibiotics, with the patient being strictly nil per mouth and receiving all feeds through a nasogastric tube (NG-tube). A repeat WS-swallow is done on day ten to confirm healing of the defect.

Results

Demographics and mechanism of injury

Over the 46-month study period, 510 patients, (452 males and 58 females) were managed for PNI. The mean age was 29.2 years (range 8–73 years). A total of 452 (89%) patients sustained stab wounds (SW) and 58 (11%) sustained gunshot wounds (GSW). A total of 202 (40%) patients sustained an isolated PNI, whilst 308 (60%) patients sustained trauma to at least one other additional anatomical region. This was for the majority of patients due to concomitant extra-cervical penetrating wounds.

Anatomical site of neck wound

A total of 387 (76%) patients sustained wounds to the anterior triangle of the neck, distributed as following: Zone I: 207 (41%), Zone II: 142 (28%), Zone III: 38 (7%). There were 61 (12%) patients with wounds to the posterior triangle and 46 (9%) patients with wounds to two or more regions of the neck. In 16 (3%) patients the wounds were not classified in the registry.

Concomitant penetrating wounds

Concomitant penetrating wounds were located to the chest in 133 (26%) patients, to the head and face area in 124 (24%) patients, to the extremities in 89 (17%) patients and to the abdomen in 48 (9%) patients.

Special investigations

A total of 387 (76%) patients underwent a CTA, of which 70 (18%) demonstrated a vascular injury. Three patients returned with a pseudo-aneurysm despite having a normal CTA on admission. This provides a false negative rate for CTA of less than one per cent (3 out of 317 negative CTAs were false negative). CTA demonstrated a vascular injury in 70 patients and of these 16 (23%) patients proceeded to have a CDA. In only 8 (50%) of these patients did CDA confirm the injury identified on CTA and a further patient with an injury demonstrated on CTA underwent a negative exploration. Nine out of 70 positive CTA's were therefore falsely positive giving a false positive rate for CTA of 13%. Of the 212 (42%) patients who underwent WS-swallow, an injury was demonstrated in 29 (14%) cases. Fifteen (3%) patients underwent endoscopy of which 11 (73%) confirmed an injury.

Management

A total of 373 (73%) patients did not require any surgical intervention and 401 (79%) were managed conservatively for PNI. Therapeutic interventions were required for 137 (27%) patients, of which 109 (21%) were for a penetrating neck wound and 28 (6%) for concomitant injuries. Of the 109 patients requiring interventions for PNI seven (6%) underwent an endovascular intervention, two (2%) a thoracoscopy for retained pleural collection, one (<1%) an incision and drainage of a neck abscess, and two (2%) required a tracheostomy without a neck exploration. The remaining 97 (89%) patients underwent formal open neck exploration. Of the 109 patients who underwent intervention for PNI 28 (26%) patients underwent emergency surgery without prior imaging. The following incisions were used: anterior lateral SCM or collar incision neck, supra-infra-clavicular incision, local wound exploration and sternotomy/thoracotomy. Only three patients underwent a negative neck-exploration, constituting 0.6% of the entire cohort and 3% of all patients explored. Two patients required open neck explorations for removal of retained blades but without any findings of further injury noticed.

Airway injury

A total of 29 (6%) patients sustained an airway injury. This included seven laryngeal injuries, which were all managed operatively, 18 cervical tracheal injuries, of which 10 were

managed conservatively and eight operatively. There were five thoracic tracheal injuries, only two of which were operated on. One patient sustained multiple GSW and sustained injuries to the trachea and larynx as well as the oesophagus. He is entered twice in Table 1.

Digestive tract injury

In the cohort 41 (8%) patients had a digestive tract injury. Twenty-four patients sustained a pharyngeal injury of which half were managed operatively either by repair or debridement and drainage. The other half, primarily isolated pharyngeal injuries, was managed conservatively. There were 16 patients with cervical-oesophageal injuries of which two were managed conservatively; one with curative intent whilst the other was selected for palliative care at the time of admission. A single patient sustained a thoracic oesophageal injury secondary to a SW to Zone I. This patient was also managed conservatively (Table 2).

Vascular injury

A total of 86 (17%) patients sustained a vascular injury secondary to PNI. Twenty-two (4%) patients had more than one injured vessel and there were 112 vascular injuries, which included seven mediastinal vessels, 47 root of neck vessels and 58 cervical neck vessels. The breakdown of these vascular injuries is presented in Tables 3–5. Seven patients sustained injuries to the great vessels of the mediastinum, with four patients having an injury to the innominate artery, two to the arch of the aorta and one to the descending aorta. There were 47 injuries to the vessels of the root of the neck, with the subclavian (13) and vertebral arteries (10) most frequently injured. Of the 58 cervical neck vessels, which were injured, the three most commonly injured ones were the internal jugular vein (31), common carotid artery (10) and internal carotid artery (6). Tables 3–5 summarize the vascular injuries and their management in this cohort of patients.

Associated injuries

Only 202 (40%) patients sustained isolated PNI, while 308 (60%) patients sustained trauma to at least one additional anatomical region. Separate penetrating wounds were responsible for the majority of these injuries, even though a significant number of chest injuries and head and maxillo-facial injuries were secondary to a juxtapositional PNI. Associated injuries were distributed as follows: chest: 222, head and maxillo-facial region: 134, extremities 89 and abdomen in 48 patients. Three (<1%) patients sustained a penetrating cardiac injury (PCI) and 146 (29%) patients a haemopneumothorax. Associated cervical injuries consisted of 31 cervical spine injuries, 18 spinal cord injuries, 26 brachial plexus injuries and four recurrent laryngeal nerve and or phrenic nerve injuries. There were 14 abdominal hollow visceral injuries, 10 solid visceral injuries, five diaphragmatic injuries and a single patient had multiple intra-abdominal vascular injuries. There were 15 long bone fractures.

Table 1
Airway injuries.

	Total	Conservative	Operative repair
Airway injury	29	13	17
Larynx	7	0	7
Cervical trachea	18	10	8
Thoracic trachea	5	3	2

One patient sustained multiple GSW and sustained injuries to the trachea and larynx as well as the oesophagus. He is entered twice in the above table.

Table 2
Digestive tract injuries.

	Total	Conservative	Operative repair	Debridement and drainage
Digestive tract injury	41	15	22	4
Pharynx	24	12	11	1
Cervical oesophagus	16	2	11	3
Thoracic oesophagus	1	1	0	0

Outcome

Missed Injuries and delayed diagnosis

Five (1,2%) patients out of 406 failed SNOM, and ultimately underwent surgical intervention. Three developed pseudo-aneurysms of small arteries, (costo-cervical artery, deep cervical artery and a branch of the facial artery), within 5–20 days of injury. All had a normal CTA on admission. Another patient developed an expanding neck hematoma, which compromised his airway. This patient also had a normal CTA at the time of admission but on neck exploration had ongoing bleeding from an injured thyroid lobe. Finally one patient developed a neck abscess requiring incision and drainage. This patient had a normal CTA and WS-swallow at the time of admission. A further five (1.2%) patients had missed injuries and required surgery. Each of these patients was referred from district hospitals to our trauma service, between five and fourteen days after the injury for further investigation and can therefore not be considered as having failed SNOM. Of these, two patients were referred for further management of pseudo-aneurysms of the subclavian and proximal axillary artery requiring primary vascular repair, and the other three for debridement and drainage of missed digestive tract injuries including two oesophageal and one pharyngeal injury.

Comparison of GSW vs. stab

Only five (9%) patients with GSW of the neck were not investigated with CTA and the reasons for this were logistical. Analysis of the two subgroups of GSW vs. stab wound demonstrated a higher incidence of vascular injuries in GSW than SW (21% vs. 16%, $p = 0{,}408$). This was not statistically significant. Patients with PNI secondary to GSWs had a statistically significant higher incidence of "clinically important cervical injuries", as defined as an injury to either; the airway, digestive tract, vascular structures, spinal column or a neurological injury. The incidence of "multiple cervical injuries", as defined as more than one injury to the above mentioned anatomical systems, and the incidence of "associated cervical injuries" was also significantly higher in the GSW cohort. The median ISS was for GSW 13 (IQR: 8–22) and for SW 9 (IQR: 4–13). This was statistically significant. Table 6 compares the two cohorts.

Mortality

There were 10 deaths in the cohort accounting for an in-hospital mortality rate of 2%. There were three GSW and seven SW in this group. No deaths could be attributed to a failure of SNOM. Four patients were selected for palliative care from time of admission due to low GCS and/or a high-level quadriplegia. Of

Table 3
Mediastinal vascular injuries.

	Total	Repair	Ligation	Stenting
Mediastinal Injury	7	5	0	2
Aorta-descending	1	0	0	1
Aorta-arch	2	2	0	0
Innominate artery	4	3	0	1

Table 4
Root of neck vascular injuries.

	Total	Conservative	Repair	Ligation	Tivs	Stent	Emboli-zation
Root of neck	47	14	17	12	1	3	1
Subclavian artery	13	1 (intimal injury)	9 (1 pseudo-aneurysm)			3 (1 failed)	
Subclavian vein	10	4	4	2			
Axillary artery	3 (2nd to PNI)		2	1 (after failed TIVS)	1 (pseudo-aneurysm) failed)		
Vertebral artery	10	7	1	2			
Thoracic duct	3			3			
Thyrocervical trunk/inf. thyroid artery	3	1 (no extra-vasation)	1	1			
Costocervical artery	1	1 (pseudo-aneurysm)					
Deep cervical artery	1			1 (pseudo-aneurysm)			
Dorsal scapular artery	1			1			
Internal thoracic artery	1			1			
Arterial trapezius muscle bleed	1						1

Table 5
Vascular injuries to the neck.

	Total	Conservative	Repair	Ligation	Stenting
Neck vessel	58	20	15	22	1
Common carotid artery	10	1	8		1
Internal carotid artery	6	2	2	2 (close to base of skull)	
External carotid artery	3	1		2	
Internal jugular vein	31	15	5	11	
External jugular vein	2			2	
Anterior jugular vein	2			2	
Branches of the ECA (facial and maxillary)	4	1		3 (1 pseudo-aneurysm)	

these one had an oesophageal injury and another two patients non-bleeding vertebral, common carotid artery and an IJV injury with a cerebral infarct. The forth patient was not investigated further. One patient died due to a concomitant PCI and the remaining five patients died as a direct consequence of exsanguination at presentation. Two of these patients, who presented in extremis, died during resuscitative attempts in the ED. In the same period the Pietermaritzburg City Morgue reported 102 deaths secondary to PNI. This gives a total mortality rate for PNI of 17%. Of the mortuary group 20 sustained a GSW and 82 sustained a SW.

Table 6
A comparison of GSW of the neck and stab wounds.

Comparison of GSW vs. SW	GSW (*N*)	SW (*N*)	GSW vs. SW
Percentage of cohort of 510 patients	11% (58)	89% (452)	
Average age in years-mean	30.8 (range 8–61)	29.0 (range 11–73)	0.29
Sex			
Female	10% (6)	9% (42)	
Male	90% (52)	91% (410)	
Weapon			
Low velocity firearm	54 patients		
Shot gun	3 patients		
Air rifle	1 patients		
Knife		293 patients	
Unknown		80 patients	
Bottle		54 patients	
Screwdriver		11 patients	
Spear		4 patients	
Other penetrating objects		10 patients	
Isolated cervical injuries	31% (18)	37% (169)	0.3
Additional injured regions	69% (40)	63% (283)	0.3
Vascular injury	21% (12)	16% (74)	0.4
Clinically important cervical injuries	55% (32)	31% (139)	<0.001
Multiple injured cervical structures	31% (18)	5% (23)	<0.001
Associated cervical injuries	59% (34)	10% (46)	<0.001
Injury severity score-median	13 (IQR: 8–22)	9 (IQR: 4–13)	0.003

Discussion

Our data suggests that SNOM of PNI remains an appropriate strategy and the results of our study are comparable to the published literature from both South Africa and North America. Table 7 summarizes the historical publications on PNI and attempts to contextualize our results. Our rate of CTA imaging (76% of all patients) is much higher than that reported in previous studies. This reflects changes in technology and that non-invasive CTA has replaced CDA. This has in our institution resulted in a degree of clinical laziness with a resultant increased use and reliance on imaging in PNI. However our yield of CTA is slightly less than 20% and this suggests that we could potentially refine our patient selection and so optimize use of this resource. There is a small (<1%) but definite risk of a false negative result using CTA and a much higher risk (13%) of a false positive result. Although we still make use of the zones of the neck to describe the injury pattern we accept that the predictive value of the site of the wound itself is no longer felt to be a reliable indicator of either the presence of an injury or of the structures injured. For these reasons good clinical assessment is still the final arbiter of management strategies in patients with a SW to the neck [13,14].

The management of SW's of the neck compared to GSW's remains controversial. Thoma et al. in Cape Town used formal CDA in their series from 2008 [9]. Similarly Mohammed in 2004 only made use of CDA and suggested that CDA is mandatory for investigation of GSW of the neck as 10 out of 23 patients without clinical signs of vascular injury had positive findings on angiogram [15]. The LA County group advocates a clinically driven selective

Table 7
Comparative data from studies on PNI.

Author/year	*N*	Successfully conservatively managed	Surgical/ endo-vascular	Negative exploration (% of *N*:% of explored)	Mortality: of total	Mortality: of conservatively managed	Mortality: of SNOM	Failed SNOM: as leading to death or need for surgery
Stein and Seaward [1]	200	67% (133)	33% (67)	3% (6/200)/9.0% (6/67)	2% (4/200)	0	0	0
Campbell and Robbs [4]	108	76% (82)	24% (26)	0/0	3% (3/108)	1% (1/82)	1% (1/82)	1% (1/82)
Narrod and Moore [5]	77	38% (29)	62% (48)	9% (7/77)/15% (7/48)	0	0	0	0
Demetriades et al. [6]	271	44% (118)	56% (153)	10% (28/271)/18% (28/153)	4% (12/271)	0.8% (1/118)	0.8% (1/118)	0.8% (1/118)
Ngakane et al. [11]	109	97% (106)	3% (3)	0/0	2% (2/109)	2% (2/106)	0	3% (3/109)
Demetriades et al. [7]	335	80% (267)	20% (68)	3% (10/335)/15% (10/68)	0.6% (2/335)	0	0	0.7 (2/269)
Demetriades et al. [8]	223	83% (185)	17% (38)	3% (6/223)/16% (6/38)	3% (6/223)	3% (5/185)	0	0
Thoma et al. [9]	203	84% (170)	16% (33)	0/0	0	0	0	0
Current study, 2015	510	79% (401)	21% (109)	0.6% (3/510)/3% (3/97)	2.0 (10/510)	1.5% (6/401)[a]	0	1% (5/406)

[a] All expected unavoidable deaths and includes 4 patients selected for palliative care at admission, due to profound neurological deficits, and 2 patients who died in the ED before surgery could be performed.

approach to investigation of these patients [8,13,14]. Our data suggest that GSW's are highly likely to be associated with an injury and as such should be aggressively investigated. Currently we obtain a CTA and WS-swallow on all patients who sustain a GSW of the neck unless CTA demonstrates the trajectory of the bullet to be away from vital structures (only 25 of 58 patients with GSW had a WS-swallow), whereas we adopt a selective approach to the investigation of SW of the neck. Fig. 1 summarizes our suggested current approach to the investigation of patients with PNI.

The vascular injures in this study were diverse and challenging to manage. Apart from a single patient operated on for a PCI and one patient selected for palliative care with an oesophageal injury, all mortality was assessed as being associated with vascular injury. Although the application of damage control principles using TIVS has been described we did not make much use of this approach [16]. Injuries to mediastinal great vessels are challenging to manage and are associated with significant morbidity and mortality. Median sternotomy provides the most complete access for anterior mediastinal vascular injury and allowed us to repair three innominate artery injuries and two aortic arch injuries. Injuries to the vessels in the neck can be approached easily through an anterior sternocleidomastoid incision.

The management of oesophageal injury and airway injury is controversial. Our parent institution has advocated the conservative management of cervical oesophageal injuries with contained extravasation on contrast swallow. In an initial study, the authors identified 29 patients with suspected cervical oesophageal injury of which only four had confirmed injury on contrast study. All four were managed non-operatively with intravenous antibiotics and nasogastric feeds until contrast studies confirmed healing [11]. The same group proceeded to ratify this approach in a larger series over a 5-year period [17]. They identified 28 patients with an oesophageal injury, all of which had odynophagia on drinking water, out of a total of 1358. Of this group 17 (61%) were managed non-operatively with no deaths and only minor septic complications. In contrast to this a number of local single center studies [18] and international multicenter studies [19,20] have demonstrated a higher complication rate and a worse outcome of oesophageal injuries. We have tended to follow this approach of mandatory exploration and repair and drainage and we treated only three

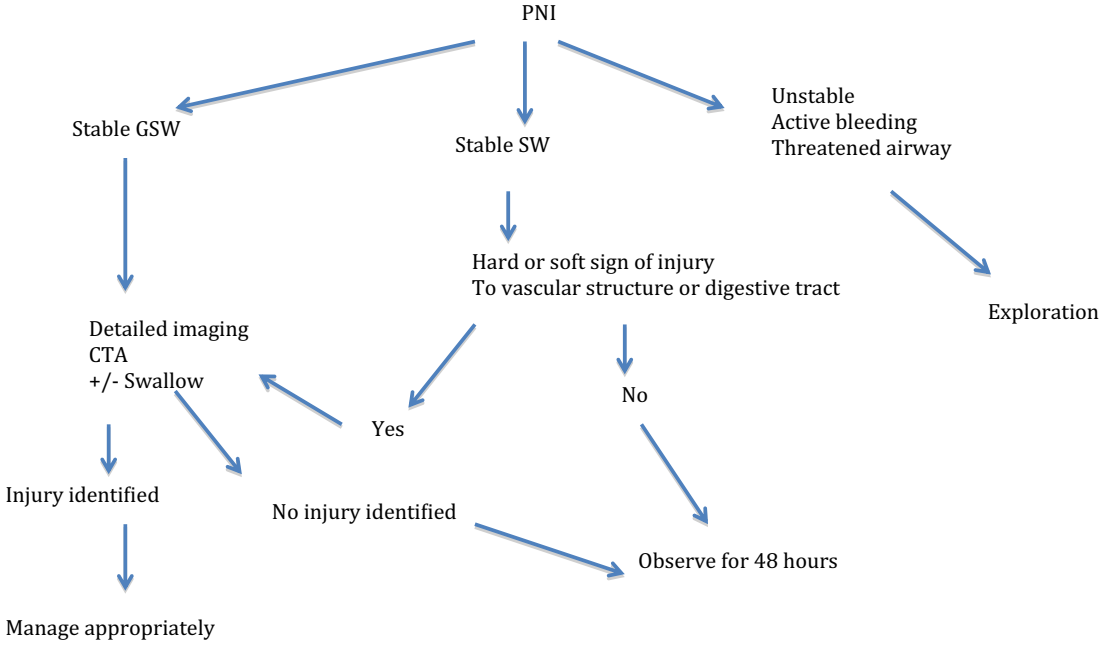


Fig. 1. Current algorithm for the management of PNI.

patients out of 17 with an oesophageal injury conservatively and one of these with a palliative intent. Further work is needed to clarify the indications for the conservative management of oesophageal injuries in our environment. In agreement with other local studies [9,10] we advocate the conservative management of isolated pharyngeal injuries. In regards to the management of airway injury equivalent results were obtained in both groups treated operatively and non-operatively and we feel that the conservative management of clinically minor airway injuries is safe. We reserve repair and tracheostomy for destructive injuries.

Conclusion

SNOM of PNI remains a safe and appropriate management strategy. The conservative management of isolated pharyngeal injuries is well supported by our findings but the role of conservative treatment of oesophageal injuries needs to be further defined. The SNOM of small non-destructive upper airway injuries seems to be a safe strategy, while destructive airway injuries require formal repair. Imaging merely for proximity is associated with a low yield. CTA has a high false positive rate of thirteen per cent and good clinical assessment remains the cornerstone of management.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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