Effectiveness of No-Zone Approach for Management of Isolated Penetrating Neck Injuries Among Hemodynamically Stable Patients. A Longitudinal Retrospective Study.

Ahmed Gaber Hassanein (ahmedgaber_74@yahoo.com)
Sohag University Faculty of Medicine https://orcid.org/0000-0002-7447-6680

Mohammed Hazem Elmoshneb
Sohag University Faculty of Medicine

Wael A. Ahmad
Sohag University Faculty of Medicine

Ahmed Abdel Kahaar Aldardeer
Sohag University Faculty of Medicine

Osama A. Ismail
Sohag University Faculty of Medicine

Research article

Keywords: no zone approach, isolated penetrating neck injuries, hemodynamically stable patients, vascular injuries, laryngotracheal injury

Posted Date: April 20th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-23041/v1

Abstract

Background: Routine neck exploration for isolated penetrating neck injuries (PNIs) in hemodynamically stable patients increases the frequency of nontherapeutic surgeries, and complications. Current management protocol involves the no zone approach which uses physical examination and computerized tomographic angiography to guide treatment plans. This work aimed to study the effectiveness and reliability of no-zone approach for management of isolated PNIs in hemodynamically stable patients.

Methods: cases of isolated PNIs in hemodynamically stable patients were managed using no zone approach. Detected injuries were managed accordingly.

Results: This study included 106 patients. 34.9% of patients were managed conservatively while surgery was done at 65.09%. Vascular management was done in 40.57%, laryngotracheal repair in 29.2%, tracheostomy in 17%, pharyngeal repair in 7.55%, esophageal repair in 6.6%, and accessory nerve repair in 2.83%. Complications occurred in 16.04% of cases in the form of vascular complications (7.5%), respiratory complications (5.7%), pharyngoesophageal complications (1.9%), infections (12.3%), and neurological complications (7.5%). The survivors were 91.5% while deaths were 8.5%.

Conclusion: The no-zone approach offers the ideal management for isolated PNIs in hemodynamically stable patients. It is advantageous over traditional approaches. Further studies are required to augment the evidence for its use as the gold standard management for such cases.

Trial registration: the study was retrospectively registered at research registry with Research Registry UIN researchregistry5385 on February 26, 2020. Keywords: no zone approach, isolated penetrating neck injuries, hemodynamically stable patients, vascular injuries, laryngotracheal injury.

Background

Penetrating neck injuries (PNIs) account for 5—10% of all trauma cases with rising incidence rates due to increased violence, traffic accidents, homicidal and suicidal attempts. The etiology and mechanism of injury are vital factors in deciding the magnitude of damage and management preference (1). PNIs carry high mortality rate up to 11% with the major vascular injuries are fatal in 65% of cases (2). Thus, decision making and approach design are important for improving the outcome, decreasing morbidity and mortality (3).

Diagnosis is achieved by physical examination and supported by supplementary studies such as computed tomography and aerodigestive endoscopy. Currently, computed tomographic angiography (CTA) is the definitive tool for diagnosis, since it is quick, easily accessible, and accurate (4).

Surgeons used to classify the neck horizontally into three zones (I, II, and III) to facilitate the approach to PNIs (5, 6). The classic management protocol for PNIs was the mandatory neck exploration to avoid

missed injuries (7, 8). It utilized the zone-based approach to guide investigations and management with very low rates of missed injuries and high rates of successful conservative management (9, 10). Its drawbacks included difficult classification of transcervical or multiple injuries, poor correlation between the external wound and the deep organ affection (11).

The Current management protocol involves the no zone approach which uses the physical examination and CTA to guide the treatment plan. It simplifies the management of PNIs and effectively identifies or excludes vascular and aerodigestive injuries. In addition, it resulted in insignificant missed lesions and insignificant negative explorations (1–2%) (11–13). CTA has high sensitivity and specificity approaching 90–100% and 93.5–100%, respectively for diagnosis of vascular injuries, thus replacing conventional angiography as the gold standard (14–17).

Routine neck exploration in HSPs increases the frequency of unneeded surgeries, iatrogenic injuries, hospital stay, and complications (18–20). Hemodynamic stability does not exclude injury to underlying structures. Similarly, soft signs of vascular injury and suspicion of vascular injury did not indicate urgent intervention but should be thoroughly investigated and closely monitored (15).

Methods

The aim of the study:

This work aimed to study the effectiveness of the no-zone approach for the management of isolated PNIs among HSPs.

Study design, setting, and population

This study was a longitudinal retrospective study. It was conducted between July 2009 and July 2019 at Maxillofacial Surgery Unit, Surgery Department, Sohag University, Egypt. It included all cases of isolated PNIs in HSPs that presented and were managed.

Inclusion criteria

All HSPs with isolated PNI who accepted to engage in the study and signed informed consent.

Exclusion Criteria

Cases with isolated PNIs in hemodynamically unstable patients, injuries in other parts of the body or cervical spine and those who declined engagement in the study or unable to sign an informed consent.

Registeration: the study was registered at Research Registry with Unique Identifying number or registration ID: researchregistry538

Ethical Approval

This work was approved by the Institutional Review Board (IRB no. 152/2019) and was accomplished according to the principles of Declaration of Helsinki (1964) as revised in 2013. All patients accepted to engage in the study and signed written informed consent.

Management approach:

1. History taking: the socio-demographic data, mechanism and etiology of injury were recorded.
2. Clinical examination:
3. General examination: patients were evaluated based on the Advanced Trauma Life Support guidelines. Tetanus toxoid prophylaxis, anti-inflammatory, and antibiotics were prescribed for all cases. Neck injury was evaluated. If the platysma was inflicted, then it was a PNI.

B. Local examination was done lookingfor the finding suggestive of the following injuries:

- laryngotracheal injuries: stridor, hemoptysis, subcutaneous emphysema, ecchymosis, hematoma, vocal cord immobility.
- pharyngo-esophageal injury: dysphagia, soft tissue crepitus, and widening of retropharyngeal space.
- vascular injury: active hemorrhage, expanding hematoma, thrills or hypovolemic shock.
- nerve injury: hoarseness of voice and cranial nerve sensory or motor deficits.
- Investigations: in addition to the routine investiagations, CTA of the neck vessels was done for all cases. If an injury to the aerodigestive structure was suspected, fiberoptic flexible esophagoscopy and bronchoscopy under general anesthesia were done.
- Management of airway and laryngotracheal injuries

Airway patency was the first priority. Tracheostomy was the preferred artificial airway, which was performed with the patient awake under local anesthesia.

Laryngotracheal injuries were repaired accordingly. Obvious skeletal fractures and accompanying soft tissue injuries necessitated open repair. Insignificant mucosal lesions or non-displaced fractures of the laryngeal skeleton were managed conservatively.

- Management of vascular injuries

After neck exploration, control of bleeding by proximal & distal control were achieved first. Extension and type of vascular injury were evaluated and method of vascular repair was planned. Intraoperative heparin

(5000 IU) was administered after vascular control and continued postoperatively by daily subcutaneous low molecular weight heparin (40 mg) to prevent the thromboembolic event. Both the proximal and distal ends of the injured vessels were cleared from any residual thrombus with Fogarty catheter and flushed with heparinized saline. Saphenous vein graft was the material of choice in need of patch or interposition graft. Repaired vessels were irrigated with saline and covered with muscles and soft tissue after placing of the suction drain. Common carotid artery (CCA) or internal carotid artery (ICA) injuries were managed by reconstruction e.g. vascular repair, patch angioplasty and /or interposition graft. Methods of carotid repair depended on the location and size of the defect. On the other hand, vessel ligation was the option for injuries of external carotid artery (ECA), internal jugular vein (IJV), external jugular vein (EJV) and other minor vessels.

1. Management of pharyngo-esophageal injury

Pharyngeal injuries were repaired with interrupted 3/0 absorbable polydioxanone sutures and a transposed sternocleidomastoid muscle flap was mobilized over the repair to seal the vascular repair from potential infection and defend against vessel 'blow-out'. Simple esophageal injuries were managed by direct suture repair and drainage, using interrupted suture of 4–0 Vicryl, while extensive injuries underwent debridement and drainage with a planned delayed repair. The operative field was washed with saline and drained (1/4 in redivac drain), and the wound was closed.

1. The complications and outcome:

The complications were classified into vascular, respiratory, pharyngoesophageal, infections, neurological, and other complications. All patients were followed up for assessment of the outcome of the management.

1. Statistical Analysis:

Data was recorded in an excel spreadsheet, processed using the Statistical Package for the Social Sciences version 20. The Chi square frequency test was used to evaluate the effectiveness of the procedures was used.

Results

Demographics and epidemiology:

This study included 106 patients. They were 90 males (84.29%) and 16 females (15.71%). Their ages ranged between 12 and 55 years with a mean of 33 ± 9.2 years. The third decade had the maximum incidence (48.57% of the cases) followed by the fourth decade (22.85%) (Table 1). PNIs were found to be more common in a low socio-economic status group (77%) than in the middle-class group (25.5 %) and higher-class group (7.5%). Mechanism of trauma included stab wounds (85.8%), firearm injuries (9.4%), cut throat (3.8%), and others (0.9%). The etiology of injury was a road traffic accident (59.4%), assault (25.5%), occupational (12.3%), and deliberate self-harm (2.8%).

Preoperative clinical data:

Examination revealed the presence of findings suggestive of vascular injury in 51 cases (48.11%), and findings suggestive of airway injury in 45cases (42.45%), while other findings were less common.

The investigations revealed that the vascular injuries were the most common lesions (40.57%) followed by laryngotracheal 38 (35.85%) Other injuries were less common (Table 1).

Table 1
preoperative data of the patients

Variable	Item	Frequency (%)
Age Groups	0-10	3 (2.6%)
	11-20	15 (12.85 %)
	21-30	34 (48.57 %)
	31-40	25 (22.85 %)
	41-50	23 (8.57 %)
	51-60	12(10.3 %)
Clinical features	Findings suggestive of air way injury	45 (42.45%)
	Findings suggestive of pharyngo-esophageal injury	8 (7.55%)
	Findings suggestive of vascular injury:	51 (48.11%)
	finding suggestive of neurologic injury	3 (2.83%)
Investigations	Vascular injuries	43 (40.57%)
	Laryngotracheal injuries	38 (35.85%)
	Thyroid gland	17 (16.04%)
	Pharyngeal injury	8 (7.55%)
	Esophageal injury	7 (6.6%)
	Accessory nerve	3 (2.83%)

Management

Thirty-seven cases (34.9%) were managed conservatively while surgery was done in 69 cases (65.09%). Vascular injuries were managed in 43 cases (40.57%), laryngotracheal repair in 31 cases (29.2%), tracheostomy in 18 cases (17%), pharyngeal repair in 8 cases (7.55%), esophageal repair in 7 cases (6.6%), and accessory nerve repair in 3 cases (2.83%).

The detected vascular injuries were in the form of arterial injuries in 11.32% of patients, venous injuries in 6.6% and combined arterial and venous injuries in 22.64%. Regarding the type of injury, incomplete transection of the vessel was the commonest followed by a complete transection of the vessel. All the great vessels of the neck were vulnerable to injuries, in addition to other small vessels. The vascular repair was done in 37 patients (34.7%) while Ligation of the injured vessel was performed in 25 injured vessels (23.58%). Techniques of vascular repair included saphenous patch angioplasty (17.92%), simple repair (8.49%), interposition vein graft was (6.6%), and PTFE patch (2.83%). The temporary carotid shunt was used in all cases of CCA and ICA injuries requiring patch angioplasty or interposition graft (Table 2).

Table 2
The details and management of vascular injuries:

Details of vascular injuries		Frequency (%)
Type of injured vessel	Arterial injuries	12 (11.32%)
	Venous injuries	7 (6.6%)
	Combined arterial & venous injuries	24 (22.64%)
Type of injury	Incomplete transection	23 (21.7%)
	Complete transaction	10 (9.44%)
	Thrombosed vessel	5 (4.76%)
	Contusion and spasm	5 (4.76%)
Injured vessel	EJV	12 (11.32%)
	CCA	8 (7.55%)
	ECA	8 (7.55%)
	IJV	8 (7.55%)
	ICA	6 (5.66%)
	Small arterial branches	4 (3.77%)
	Small veins	3 (2.83%)
Vascular repair 37 (34.9%)	Venous patch angioplasty	19 (17.92%)
	Simple repair	9 (8.49%)
	Interposition vein graft	7 (6.6%)
	PTFE patch angioplasty	3 (2.83%)
Vessel ligation 25 (23.58%)	Ligation of EJV	12 (11.32%)
	Ligation of ECA	8 (7.55%)
	Ligation of IJV	8 (7.55%)
	Ligation of small arteries	5 (4.72%)
	Ligation of small veins	3 (2.83%)

CCA: Common carotid artery; ICA: Internal carotid artery; ECA: External Carotid Artery; IJV: Internal jugular vein; EJV: External jugular vein

Note: This table should appear in the RESULTS section at the end of the paragraphs reporting "Management" and before the subtitle "Complications and outcome"

Complications and outcome

Complications were detected in 17 cases (16.04%). Vascular complications were the commonest. They were detected in 8 cases (7.5 %) in the form of severe intraoperative hemorrhage in 3 cases, severe post-operative hemorrhage (carotid blow-out) in 3 cases, and hemiplegia due to cerebral infarction in 2 cases. Respiratory complications were detected in 6 cases (5.7 %) in the form of tracheal stenosis in 3 cases and permanent tracheostomy in 3 cases. Two cases had pharyngoesophageal complications; pharyngocutaneous fistula in one patient and tracheoesophageal fistula another one. Infections occurred in 13 cases (12.3 %) in the form of five cases of wound infection, three cases got aspiration pneumonitis, two cases developed neck abscesses, and two cases with stitch sinus. Neck infection and descending mediastinitis were seen in one patient. Neurological complications were reported in 8 cases (7.5%) in the form of hoarseness voice in 4 cases, aphonia in 2 cases, and drop shoulder (accessory nerve) in 2 cases. Other complications were seen in 9 cases (8.5%), in the form of hypertrophic ugly scar or keloid in 8 cases and chylous fistula in one patient (Table 3).

Table 3
The complications of management isolated penetrating neck injuries in hemodynamically stable patients

Type of complications	Details	Frequency (%)
Vascular (8 = 7.5 %)	Severe Intraoperative hemorrhage	3 (2.8%)
	Severe Post-operative hemorrhage	3 (2.8%)
	Hemiplegia	2 (1.9%)
Respiratory (6 = 5.7 %)	Tracheal stenosis	3 (2.8%)
	Permanent tracheostomy	3 (2.8%)
Pharyngoesophageal (2 = 1.9%)	Pharyngocutaneous fistula	1 (0.9 %)
	Tracheoesophageal fistula	1 (0.9 %)
Infections (13 = 12.3 %)	Wound infection	5 (4.7%)
	Neck abscess	2 (1.9%)
	Aspiration pneumonitis	3 (2.8%)
	Stitch sinus	2 (1.9%)
	Neck Infection and descending mediastinitis	1 (0.9 %)
Neurological (8 = 7.5%)	Hoarseness voice	4 (3.8 %)
	Aphonia (vocal cord paralysis)	2 (1.9%)
	Drop shoulder (accessory nerve)	2 (1.9%)
Others (9 = 8.5%)	Hypertrophic or ugly scar / keloid	8 (7.5%)
	Chylous fistula	1 (0.9 %)

The follow-up period ranged between six months to five years with a mean of 23 ± 4.2 months. The survivors were 97 (91.5%) while the number of deaths was 9 (8.5%)

The Frequency distribution of the data was tested for the hypothesis for the efficiency of the surgical procedure using Chi square frequency.The tests showed significant results ($p<0.05$).

Discussion

PNIs are common and present in about 5–10% of trauma patients (21). Evaluation, diagnosis, and treatment of PNIs are challenging. Also, there is a major debate on decision making and approach in these injuries. The mandatory surgery has been substituted by a more selective and conservative approach (18, 22).

Demographics and epidemiology:

In this study, there was a predominance of males (84.29%) than females (15.71%) with a maximum incidence in the third decade (48.57%) and the fourth decade (22.85%) and in the low socio-economic status group (77%). A low rate of incidence was reported in children below 10 years (2.6%) and a higher-class group (7.5%). Generally, PNIs are common in young males in the 3rd and 4th decades of and are uncommon in children (23–25). This is because the middle-aged males and low socioeconomic groups are more involved in daily activities and violence (26, 27).

In the current study, PNIs were commonly caused by stab wounds (85.5%) which were in most cases secondary to road traffic accidents (59.4%) and to a less extent due to assaults (25.5%). On the contrary, Lydiatt et al (28) revealed that, in the United States, most PNIs were secondary to assaults while some cases are caused by accidents, such as falling on sharp objects and motor vehicle accidents. This difference can be explained by the presence of less violence in our country.

Preoperative data:

In agreement with other studies (10, 13, 15, 29), our cases had a high incidence of the manifestations of vascular injuries in 51 cases (48.11%) followed by the findings suggestive of airway injury in 45cases (42.45%). The pharyngo-esophageal and neurologic injuries were less common. The affection of aerodigestive structures is less because they locate deep in the neck and are more protected by the surrounding structures.

In our study, vascular injuries were the most common lesions detected by CTA in two-fifths of the cases (40.57%). Also, CTA was capable to detect injuries in other structures such as thyroid gland laryngotracheal, esophagus, and pharynx. With the assistance of other investigation, the laryngotracheal injuries were found in 35.85% of cases, thyroid gland injuries in 16.04%, pharyngeal and esophageal injuries in 7.55% and 6.6% of cases respectively. Accessory nerve injury was noticed in 2.83%. Other studies reported that arterial injury occurred in approximately 25% of PNIs (30). Aerodigestive injuries were detected in 23–30% of cases with PNIs (31). Pharyngo-esophageal injuries were less common than laryngotracheal injuries (1, 32). Neurological structures included spinal cord, the sympathetic chain, cranial nerves VII-XII, peripheral nerve roots, and brachial plexus (33).

In agreement with our strategy in the management of HSPs, Biffl WL et al. (9) used CTA to evaluate patients who didn’t need immediate surgery. This radiological option has high sensitivity and specificity in the detection of vascular, laryngotracheal and many pharyngo-esophageal injuries, thereby it eliminates the role of other imaging investigations in the assessment of different types of injuries. In addition, it can offer data on the pathway of the injury and delineate the need for imaging of the chest. CTA has led to a marked reduction in classic neck explorations. (12, 15, 24, 25, 29)

CTA has the probability of missing pharyngo-esophageal injuries, with some studies reported its sensitivity to be nearly 53%. (9, 32) In accordance with other studies, we used the contrast swallow and fiberoptic flexible esophagoscopy to evaluate the pharyngoesophageal and laryngotracheal injuries. The pharyngeal injury was detected in 8 cases (7.55%) and esophageal injury in 7 cases (6.6%). Bronchoscopy detected laryngotracheal injury in 38 cases (35.85%). Lourencao J et al. (24) appreciated that additional imaging in stable patients with the potential pharyngo-esophageal injury. Contrast swallow should be done and to be accompanied by a flexible esophagoscopy in doubtful diagnosis. Flexible esophagoscopy has a sensitivity close to 100%.

According to the obtained data in this study, CTA is advised as a routine tool in all cases of PNIs in HSPs. Additional evaluation using bronchoscopy, contrast swallow / flexible esophagoscopy may be directed by CTA results (11).

Management

In our series, 34.9 % of cases required no surgical intervention and were managed conservatively. Nason et al. (34) and Van Waes et al. (17) concluded in two different studies that observation in asymptomatic patients is adequate in the first instance.

In this study, we followed the no zone approach for the management of PNIs because it was safe and feasible with few negative explorations and no missed injury (9, 35–37). Also, we avoided routine neck exploration and adopted planned customized surgical intervention according to the expected injuries in each case. Surgical intervention was done in 69 cases (65.09%). Statistical analysis showed that the no zone approach had a clinical and statistical significance in the management of PNIs in this study. Similar to Thoma et al. (35) who developed a management algorithm based on clinical examination and CTA for patients with PNI, we found that no surgical exploration was negative, and no injury was unnoticed. We think CTA is essential to guide surgical intervention. It is a fast, accurate, noninvasive method of evaluating PNIs in HSPs with improvement in the detectability of vascular injuries and extravascular injuries.

- Management airways and laryngotracheal injuries

In our study, evaluation of laryngotracheal trauma was first assessed aiming to ensure a patent airway. If an injury of the laryngotracheal complex is expected, pan-endoscopy and bronchoscopy under general anesthesia should be done before surgical intervention (11, 30). If an injury is detected, surgical repair is mostly indicated, except for minor mucosal tears or non-displaced fractures of the laryngeal skeleton, that can be treated conservatively (11). Major fractures and accompanying soft tissue lesions require open surgical repair (4).

In this study, tracheostomy was performed in 17 % of cases to establish patent airways. Also, laryngotracheal repair was done in 29.2% of cases. Jarviket al. (27) reported that laryngeal repair was

required in 31% of cases. Nason et al. (34) found that airway repair was required in 37% of cases.

In accordance with other studies, tracheostomy was the preferred artificial airway. Tracheotomy was performed as low as possible to prevent further injury to the laryngotracheal complex. Most authors agree that blind intubation methods should be avoided in these circumstances because more injuries or complete airway obstruction may result (2, 38, 39). Tracheotomy was indicated if there was the skeletal collapse, partial or complete transection severe interruption of the laryngotracheal complex (26).

- Management of vascular injuries

Saito et al. (30) reported that arterial injuries were reported in about 25% of PNIs; out of them, the carotid arteries were affected by 80%. In this study, the vascular injuries were detected in 40.57% of cases. With respect to the type of the involved vessel, the arteries were more involved than veins. Isolated arterial injuries were found in 11.32% of the cases while isolated venous injuries in 6.6% in addition to the combined arterial & venous injuries (22.64%). The commonest form was incomplete transactions (21.7%), followed by complete transection (9.44%). Other less common injuries were thrombosed vessels (4.77%) or contusion with spasm (4.77%). In accordance with Bodanapally et al. (40) we find that all neck arteries are vulnerable to injury. In our study, we found that both CCA and ECA were equally affected (7.55%), while ICA was less affected (5.66%). Also, EJV injuries (11.32%) were more common than the IJV injuries (7.55%).

Surgical approach to vascular injuries was variable e.g. simple vascular repair, venous or synthetic patch angioplasty or interposition grafts may be used in extensive injuries. Temporary carotid shunt can be utilized in complicated injuries. In our study, the repair of ICA and CCA was the rule during management to obtain a favorable outcome. The method of repair depended on the site and size of the injury. The commonly used techniques include simple repair and vein or thin-walled polytetrafluoroethylene (PTFE) patch angioplasty (40). In our study, vascular repairs were achieved first before other associated injuries to establish favorable results. Arterial injury repair was the principle in all cases of CCA and ICA injuries. They included vein patch angioplasty in 17.92% of cases, simple repair in 8.49 % of cases, interposition vein graft was done in 6.6 % of cases, PTFE patch angioplasty in 2.83 % of cases. Ligation of the injured vessel was the rule in cases of IJV, EJV, and ECA injuries especially in difficult and combined vascular injuries as the repair was time-consuming non vital. Ligation was a simple and rapid way to avoid severe or uncontrollable bleeding. It was done in 23.58 % of cases e.g. small arterial branches, ECA, EJV, and IJV. We avoided ligation of CCA or ICA. We agree Toit et al. (41) who reported that ligation of these vessels especially in complete arterial transection, severe uncontrollable bleeding, presence of hypovolemic shock and failed all attempts to control bleeding had poor outcome as it carries 50% mortality rate and 30% risk of stroke.

- Management of pharyngo-esophageal injuries

In our study, pharyngeal repairs were done in 8 cases (7.55%), while esophageal repairs were performed in 7 cases (6.6%). The pharyngeal and esophageal injuries are uncommon because of their protected deep

central location. They are difficult to detect as they have no clear clinical findings.

In our study, the injuries were debrided, and single-layer repair was performed with proper drainage and a sternomastoid muscle flap was utilized in large injuries or when there was associated tracheal or vascular injury(42). This is because all repairs of the carotid artery are liable to postoperative blow-out if there has been an associated esophageal injury (43). Most of the studies advocate that single-layer repair is equally safe and effective as a double-layer repair in PNIs. We agree that in the patients who show hard signs of pharyngeal / esophageal injury or if imaging investigations detect perforation, surgical repair is indicated (35). If not treated early, these injuries can lead to mediastinitis and abscess or empyema formation due to leakage of their contents (34).

Management of esophageal injuries is controlled by the time since the occurrence of injury. Patients attending within 12 hours of trauma may be subjected to immediate repair and drainage (34), while for those presenting after 12 hours, morbidity and mortality are high and immediate repair is more likely to be unsuccessful (34, 36). These patients should undergo debridement and drainage with a planned delayed repair (27).

Complications and outcome

In this study, complications were noticed in 17 cases (16.04%). Infections were the commonest. They occurred in 12.3 % of cases and required aggressive treatment because they were extensive and might be lethal in some instances e.g., neck infection and descending mediastinitis, aspiration pneumonitis, and neck abscess. Death occurred in one case of neck infection and descending mediastinitis and in another case with aspiration pneumonitis. Other less dangerous forms of infections were wound infection and stitch sinus. Vascular complications were detected in 7.5% in the form of uncontrolled intraoperative hemorrhage, severe post-operative hemorrhage (carotid blow-out) each was reported in 3 cases where we failed to control bleeding and all these cases died due to hypovolemic shock. Hemiplegia secondary to cerebral infarction was noticed in 2 cases. Respiratory complications were encountered in 6 cases (5.7 %) in the form of tracheal stenosis in 3 cases, permanent tracheostomy in 3 cases. Pharyngoesophageal complications were seen in two cases (1.9%), one had pharyngocutaneous fistula which healed three weeks after conservative treatment, and another one had a tracheoesophageal fistula. The later was subjected to unsuccessful operation for fistula repair and complicated by death. Neurological complications were reported in 8 cases (7.5%). Four cases got hoarseness voice and two cases had aphonia due to injuries to recurrent laryngeal nerves. They were referred to the speech clinic for further management. Two cases developed drop shoulder due to failure of the accessory nerve repair and they were sent to the physiotherapy department for treatment. Other complications were seen in 9 cases, eight cases developed either hypertrophic ugly scar or keloid and one patient had chylous fistula which was managed successfully by another surgery two months later.

In a study by Nason et al. (34) 11 patients developed complications (15.71%) of which, 4 patients had hoarseness of voice (5.71%) and 3 cases developed tracheal stenosis (4.28%). Lydiatt et al. (28) found

that vascular injuries induced complications in 40% of cases of PNIs.

In our study, the survivors were 97 (91.5%) while the number of deaths was 9 (8.5%). Demetriades et al. (3) reported that PNIs are associated with a mortality of 3–10% and 50% of these deaths were attributed to hemorrhage while esophageal injuries are associated with mortality rates of 11–17% (28).

In this study, more than two-thirds of deaths (6/9) were associated with vascular complications both the intraoperative and postoperative hemorrhage, followed by infections where death occurred in 2 cases; one case with neck infection and descending mediastinitis and another with aspiration pneumonitis. Pharyngoesophageal complications were related to the least mortality where death was reported in a case with tracheoesophageal fistula. Others reported that vascular injuries were associated with half the mortality cases. tracheal injury was responsible for about one fifth the mortalities (32). Also, esophageal injuries can lead to leakage of swallowed materials into surrounding tissues with sepsis and death (44).

Conclusion

The no-zone approach offers the ideal management for isolated PNIs in HSPs. CTA is advised as a routine tool in all cases. Additional evaluation using bronchoscopy, contrast swallow/flexible esophagoscopy may be directed by the CTA results. The commonest injuries were the vascular injuries which were associated with higher morbidity and mortality. Data is gathering to advocate that the non-zonal approach is advantageous over traditional approaches, especially with respect to HSPs. Further studies are required to augment the evidence for the use of the no-zone approach as the gold standard for management for PNIs in HSPs.

List Of Abbreviations

- PNIs: penetrating neck injuries.
- HSPs: hemodynamically stable patients.
- CTA: computed tomographic angiography.
- CCA: common carotid artery.
- ICA: internal carotid artery.
- ECA: external carotid artery.
- IJV: internal jugular vein.
- EJV: external jugular vein.

Declarations

Ethics approval and consent to participate: This work was approved by the Institutional Review Board (IRB no. 152/2019) and was accomplished according to the principles of Declaration of Helsinki (1964) as revised in 2013. All patients accepted to engage in the study and signed written informed consent.

Consent for publication: not applicable.

Availability of data and materials:

- The datasets generated and/or analysed during the current study are available in the research registery repository, https://www.researchregistry.com/browse-the-registry#home/registrationdetails/5e56cf5573f3d90017287787/
- The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: no fund was received for this study.

Author contribution: All authors made substantial contributions to all of the following:

- Study conception and design
- Acquisition of data
- Analysis and interpretation of data
- Drafting of manuscript
- Critical revision of the manuscript
- Final approval of the version to be submitted.

Acknowledgements: not applicable.

References

1.Mahmoodie M, Sanei B, Moazeni-Bistgani M, Namgar M. Penetrating neck trauma: review of 192 cases. Archives of trauma research. 2012;1(1):14.

2.Ozturk K, Keles B, Cenik Z, Yaman H. Penetrating zone II neck injury by broken windshield. International wound journal. 2006;3(1):63–6.

3.Demetriades D, Theodorou D, Cornwell E, Berne T, Asensio J, Belzberg H, et al. Evaluation of penetrating injuries of the neck: prospective study of 223 patients. World journal of surgery. 1997;21(1):41–8.

4.Apffelstaedt JP, Med M, Müller R. Results of mandatory exploration for penetrating neck trauma. World journal of surgery. 1994;18(6):917–9.

5.Thal ER, Meyer DM. Penetrating neck trauma. Current problems in surgery. 1992;29(1):5–56.

6.McConnell DB. Management of penetrating trauma to the neck. Adv Surg. 1994;27:97–127.

7.Fogelman MJ, Stewart RD. Penetrating wounds of the neck. The American Journal of Surgery. 1956;91(4):581–96.

8.Fitchett VH, Pomerantz M, Butsch DW, Simon R, Eiseman B. Penetrating wounds of the neck: a military and civilian experience. Archives of Surgery. 1969;99(3):307–14.

9.Biffl WL, Moore EE, Rehse DH, Offner PJ, Franciose RJ, Burch JM. Selective management of penetrating neck trauma based on cervical level of injury. The American journal of surgery. 1997;174(6):678–82.

10.Low GM, Inaba K, Chouliaras K, Branco B, Lam L, Benjamin E, et al. The use of the anatomic 'zones' of the neck in the assessment of penetrating neck injury. The American Surgeon. 2014;80(10):970–4.

11.Bhatt NR, McMonagle M. Penetrating neck injury from a screwdriver: can the No Zone approach be applied to Zone I injuries? Case Reports. 2015;2015:bcr2015212666.

12.Inaba K, Branco BC, Menaker J, Scalea TM, Crane S, DuBose JJ, et al. Evaluation of multidetector computed tomography for penetrating neck injury: a prospective multicenter study. Journal of Trauma and Acute Care Surgery. 2012;72(3):576–84.

13.Shiroff AM, Gale SC, Martin ND, Marchalik D, Petrov D, Ahmed HM, et al. Penetrating neck trauma: a review of management strategies and discussion of the 'No Zone'approach. The American surgeon. 2013;79(1):23–9.

14.Inaba K, Munera F, McKenney M, Rivas L, De Moya M, Bahouth H, et al. Prospective evaluation of screening multislice helical computed tomographic angiography in the initial evaluation of penetrating neck injuries. Journal of Trauma and Acute Care Surgery. 2006;61(1):144–9.

15.Osborn TM, Bell RB, Qaisi W, Long WB. Computed tomographic angiography as an aid to clinical decision making in the selective management of penetrating injuries to the neck: a reduction in the need for operative exploration. Journal of Trauma and Acute Care Surgery. 2008;64(6):1466–71.

16.de Régloix SB, Baumont L, Daniel Y, Maurin O, Crambert A, Pons Y. Comparison of penetrating neck injury management in combat versus civilian trauma: a review of 55 cases. Military medicine. 2016;181(8):935–40.

17.Van Waes O, Cheriex K, Navsaria P, Van Riet P, Nicol A, Vermeulen J. Management of penetrating neck injuries. British Journal of Surgery. 2012;99(S1):149–54.

18.Zaidi SMH, Ahmad R. Penetrating neck trauma: a case for conservative approach. American journal of otolaryngology. 2011;32(6):591–6.

19.Osborn TM, Bell RB, Qaisi W, Long WB. CT angiography as an aid to clinical decision making in the selective management of penetrating injuries to the neck: A reduction in the need for operative exploration. British Journal of Oral and Maxillofacial Surgery. 2007;45(7):e33-e4.

20.Roepke C, Benjamin E, Jhun P, Herbert M. Penetrating Neck Injury: What's In and What's Out? Annals of emergency medicine. 2016;67(5):578–80.

21.Demetriades D, Skalkides J, Sofianos C, Melissas J, Franklin J. Carotid artery injuries: experience with 124 cases. The Journal of trauma. 1989;29(1):91–4.

22.Golueke PJ, Goldstein AS, Sclafani S, Mitchell WG, Shaftan GW. Routine versus selective exploration of penetrating neck injuries: a randomized prospective study. The Journal of trauma. 1984;24(12):1010–4.

23.Bahten LCV, Duda JR, Zanatta PDS, Morais ALd, Silveira F, Olandoski M. Neck injuries: retrospective analysis of 191. Revista do Colégio Brasileiro de Cirurgiões. 2003;30(5):374–81.

24.Lourencao J, Nahas S, Margarido N, Rodrigues AJ, Birolini D. Penetrating trauma of the neck: prospective study of 53 cases. Revista do Hospital das Clínicas. 1998;53(5):234–41.

25.Corneille MG, Gallup TM, Villa C, Richa JM, Wolf SE, Myers JG, et al. Pediatric vascular injuries: acute management and early outcomes. Journal of Trauma and Acute Care Surgery. 2011;70(4):823–8.

26.Vijayashree MS, Viswanatha B, Vincent P, Ravikumar R, Krishna N. Clinical Evaluation and Management of Penetrating Neck Injuries. 2014.

27.Jarvik JG, Philips G, Schwab CW, Schwartz JS, Grossman RI. Penetrating neck trauma: sensitivity of clinical examination and cost-effectiveness of angiography. American journal of neuroradiology. 1995;16(4):647–54.

28.Lydiatt M, Snyder C, Lydiatt D. Penetrating Injuries of the Neck: Follow-up.; 2009 [updated].

29.Burgess C, Dale O, Almeyda R, Corbridge R. An evidence based review of the assessment and management of penetrating neck trauma. Clinical Otolaryngology. 2012;37(1):44–52.

30.Saito N, Hito R, Burke PA, Sakai O. Imaging of penetrating injuries of the head and neck: current practice at a level I trauma center in the United States. The Keio journal of medicine. 2014;63(2):23–33.

31.Sperry JL, Moore EE, Coimbra R, Croce M, Davis JW, Karmy-Jones R, et al. Western Trauma Association critical decisions in trauma: penetrating neck trauma. Journal of Trauma and Acute Care Surgery. 2013;75(6):936–40.

32.Bryant AS, Cerfolio RJ. Esophageal trauma. Thoracic surgery clinics. 2007;17(1):63–72.

33.Rhee P, Kuncir EJ, Johnson L, Brown C, Velmahos G, Martin M, et al. Cervical spine injury is highly dependent on the mechanism of injury following blunt and penetrating assault. Journal of Trauma and Acute Care Surgery. 2006;61(5):1166–70.

34.Nason RW, Assuras GN, Gray PR, Lipschitz J, Burns CM. Penetrating neck injuries: analysis of experience from a Canadian trauma centre. Canadian Journal of Surgery. 2001;44(2):122.

35.Thoma M, Navsaria PH, Edu S, Nicol AJ. Analysis of 203 patients with penetrating neck injuries. World journal of surgery. 2008;32(12):2716.

36.Siau RT, Moore A, Ahmed T, Lee MS, Tostevin P. Management of penetrating neck injuries at a London trauma centre. European archives of oto-rhino-laryngology. 2013;270(7):2123–8.

37.Prichayudh S, Choadrachata-anun J, Sriussadaporn S, Pak-art R, Sriussadaporn S, Kritayakirana K, et al. Selective management of penetrating neck injuries using “no zone” approach. Injury. 2015;46(9):1720–5.

38.Verschueren DS, Bell RB, Bagheri SC, Dierks EJ, Potter BE. Management of laryngo-tracheal injuries associated with craniomaxillofacial trauma. Journal of oral and maxillofacial surgery. 2006;64(2):203–14.

39.Tallon JM, Ahmed JM, Sealy B. Airway management in penetrating neck trauma at a Canadian tertiary trauma centre. Canadian Journal of Emergency Medicine. 2007;9(2):101–4.

40.Bodanapally UK, Dreizin D, Sliker CW, Boscak AR, Reddy RP. Vascular injuries to the neck after penetrating trauma: diagnostic performance of 40-and 64-MDCT angiography. American Journal of Roentgenology. 2015;205(4):866–72.

41.Du Toit D, Coolen D, Lambrechts A, Odendaal JdV, Warren B. The endovascular management of penetrating carotid artery injuries: long-term follow-up. European Journal of Vascular and Endovascular Surgery. 2009;38(3):267–72.

42.Moeng S, Boffard K. Penetrating neck injuries. Scandinavian journal of surgery. 2002;91(1):34–40.

43.Levine EA, Alverdy JC. Carotid-esophageal fistula following a penetrating neck injury: case report. The Journal of trauma. 1990;30(12):1588–90.

44.Singh RK, Bhandary S, Karki P. Managing a wooden foreign body in the neck. Journal of Emergencies, Trauma and Shock. 2009;2(3):191.