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Field Guide to Managing Penetrating Neck Injuries: A Practical Approach for Paramedicsin the Saudi red crescent authority

Abdulaziz Ali Fayea Asiri[1], Essa Ali Abdullah Algasher[2], Hassan Ali Hassan Alqumri[3], Khalid Yahya Hussain Almaghyadi[4], Ahmed Hassan Mohmmed Asiri[5], Ibrahim Salem AliQithlan[6], Ahmed Mohammed Ahmed Asiri[7], Ahmad Nasser Mohammed Al Arrafi[8], Mohammed Hassen Mohammed AL Thawabi[9], Mousa Ibrahim Yahya[10].

1. EMT, Red Crescent Authority, Kingdom of Saudi Arabia. abuturky201506@gmail.com
2. EMT, Red Crescent Authority, Kingdom of Saudi Arabia. essa888022@gmail.com
3. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.haassiri.8808@hotmail.com
4. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.Khaldalmghydy@gmail.com
5. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.ahmedksa331@gmail.com
6. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.Srca06377@srca.org.sa
7. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.ahmed.damas42@gmail.com
8. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.cod997red@hotmail.com
9. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.mbbxzz3@gmail.com
10. EMT, Red Crescent Authority, Kingdom of Saudi Arabia.Mooosa1401@gmail.com

Abstract
Penetrating neck injuries (PNIs) are complex and life-threatening traumas that pose significant challenges for pre-hospital care providers. Despite accounting for only 1% of all trauma cases, PNIs are associated with mortality rates ranging from 3% to 6%. While hospital-based guidelines exist, there is currently no universally accepted consensus or standardized recommendations for the pre-hospital management of PNIs. This review aims to address this critical knowledge gap by outlining management principles to inform a standardized approach for paramedics, aligning with their scope of practice and operational guidelines. The neck's anatomy is divided into three zones, each housing vital structures vulnerable to injury. The most frequently injured structures are vascular elements, followed by the respiratory and digestive tracts. Initial assessment categorizes findings into "hard" and "soft" signs, guiding the evaluation of injury severity. Uncontrolled hemorrhage is a leading cause of morbidity and mortality, and hemostatic dressings have demonstrated effectiveness in achieving hemostasis in pre-hospital settings. Airway management decisions should be made on a case-by-case basis, with rapid sequence intubation being the preferred method when indicated. Front of neck access may be necessary in "cannot intubate, cannot ventilate" scenarios. Circulation management focuses on hemorrhage control, hemostatic volume resuscitation, and preventing trauma-induced coagulopathy. Neurological injuries are rare but can cause severe deficits, and routine spinal immobilization is not recommended in isolated PNIs. A proposed management algorithm synthesizes current knowledge and provides a structured approach to assessment and intervention in pre-hospital environments. Future research should focus on refining best practices, comparing intubation techniques, evaluating hemostatic agents, and exploring the impact of interventions on secondary brain injury. Incorporating a shared, structured mental model into clinical protocols may enhance the rapid and effective management of PNIs, improving patient outcomes during transfer to definitive care.
Keywords: paramedics, Penetrating Neck Injuries, PNIs

Introduction

Penetrating neck injuries (PNIs) are characterized as trauma to the neck that breaches the platysma muscle layer. These injuries present a distinct and complex challenge for pre-hospital care providers, particularly paramedics who often operate in resource-constrained environments. Effective and timely management in these critical, time-sensitive situations is essential for achieving favorable patient outcomes. According to previous studies, PNIs account for approximately 1% of all trauma cases, with mortality rates reported to range between 3% and 6%.

Recent advancements in research have largely concentrated on the management of PNIs once the patient has arrived at the emergency department. These investigations have informed recommendations and protocols, including criteria for surgical intervention and the application of computed tomographic angiography to assist clinical decision-making (Sperry et al., 2013).

However, despite the availability of hospital-based guidelines, there is currently no universally accepted consensus or standardized recommendations specifically addressing the pre-hospital management of PNIs. To the best knowledge of the authors, no such consensus exists at the time of writing. This gap in standardized guidance creates variability in pre-hospital care practices, potentially influencing patient outcomes.

This review seeks to address this critical knowledge regarding the pre-hospital management of PNIs. The objective is to outline management principles that can inform the establishment of a standardized approach for paramedics. These principles are designed to align with the scope of practice and operational guidelines of emergency medical services (EMS), empowering paramedics with clear and actionable protocols to enhance patient outcomes in the field.

Anatomy of the Neck

The anterior region of the neck is anatomically delineated by the angle of the mandible superiorly, the sternal notch inferiorly, the clavicles laterally, and the spinous process of the seventh cervical vertebra posteriorly. Covering the anterior aspect is the subcutaneous platysma muscle, which serves as a marker for defining penetrating cervical trauma. Any injury breaching this muscular layer is classified as “penetrating” (Sperry et al., 2013).

A widely recognized anatomical classification for cervical injuries is the one proposed by Monson et al. This system divides the neck horizontally into three superimposed zones, forming the basis for therapeutic decisions. Another classification by Osborn organizes the neck into three vertical compartments: two lateral and one central. Lateral compartment injuries typically involve the jugulo-carotid axis and almost always require surgical exploration. Conversely, injuries in the central compartment, encompassing the upper aero-digestive tracts, may initially be managed medically or endoscopically based on clinical presentation.

Despite the utility of the Osborn classification, this review will adopt the Monson classification, as it remains the most widely used framework among surgeons and underpins decades of recommendations for managing neck injuries.

Zone I

Zone I refers to the lower region of the neck, extending from the clavicles to the cricoid cartilage. The vascular structures within this zone include the major vessels supplying the brain, face, and upper extremities, such as the common carotid arteries, jugular veins, and subclavian arteries and veins. The brachial plexus, vagus nerve, and recurrent laryngeal nerves are the significant nervous elements, while the trachea and pulmonary apex represent the respiratory structures. The esophagus, located posteriorly, is relatively shielded, whereas the thyroid gland, being superficial, is highly exposed to penetrating injuries. Additionally, skeletal structures like the clavicles and cervical vertebrae may also be affected.

Zone II

Zone II, or the mid-zone, extends between the cricoid cartilage and the mandibular angles. Key vascular elements include the terminal segments of the common carotid arteries, their bifurcations into internal and external carotid arteries, and the internal jugular vein. Nervous structures include the vagus and recurrent laryngeal nerves, with the latter innervating the vocal cords. The larynx and upper trachea represent the respiratory elements, while intestinal structures such as the upper esophagus and oropharynx may also sustain injuries, depending on the trauma's trajectory.

Zone III

Zone III, the uppermost region, spans from the mandibular angles to the skull base. It is bounded anteriorly by the mandibular branches, posteriorly by the mastoid processes, and superiorly by the foramen magnum. This zone houses vulnerable vascular structures such as the internal carotid arteries and internal jugular veins near their cranial entry or exit points. Nervous elements include cranial nerves (e.g., the facial nerve's marginal mandibular branch, vagus nerve, and spinal accessory nerve) and cervical spinal cord components, which, while relatively protected by the cervical vertebrae, remain susceptible to injury. Additional structures at risk include the parotid gland, Stensen's duct, and the temporomandibular joint.

Epidemiology

Cervical injuries are generally categorized into two primary contexts. The first involves military and combat-related trauma. Historical data, tracing back to the Napoleonic Wars, suggest that advances in personal protective equipment have reduced immediate fatalities, enabling more patients to survive cervical and facial injuries. Recent military studies estimate that cervico-facial injuries account for approximately 25% of all injuries in this context (Lanigan et al., 2017).

The second context pertains to civilian injuries, arising from incidents such as assaults, terrorist attacks, urban violence, public demonstrations, and natural disasters. Although their precise prevalence is challenging to ascertain, non-military penetrating cervical trauma is estimated to constitute 5–10% of all trauma cases (Saito et al., 2014). Despite this relatively low proportion, certain studies report mortality rates as high as 10%. Civilian injuries predominantly involve stab wounds (e.g., assaults, self-harm), followed by gunshot wounds and vehicular accidents (Burgess et al., 2012; Mahmoodie et al., 2012).

In military settings, ballistic injuries, primarily caused by shrapnel, are most common and frequently occur alongside other injuries, resulting in multi-trauma scenarios [8]. Management principles for military injuries generally align with those for civilian trauma (De Régloix et al., 2016).

Regarding stab wounds, Zone I is affected in approximately 50% of cases, while Zones II and III each account for 25%.

Lesions

The neck is a junctional anatomical region containing multiple vital structures, making it highly vulnerable, especially in civilian scenarios where external protection is lacking. The most frequently injured structures are vascular elements, where complications can include hemorrhage, partial or complete vascular occlusion, dissection, pseudoaneurysm formation, or arteriovenous fistulas— the latter being the most common consequence of unrecognized vascular injuries (Babu et al., 2017). Approximately 25% of PNIs involve arterial structures, with 80% affecting the carotid arteries. Vertebral artery injuries occur in fewer than 50% of cases, and the overall mortality rate for vascular injuries approaches 60%.

Injuries to the respiratory and digestive tracts each account for roughly 25% of cases. Laryngo-tracheal injuries are common and can result in life-threatening airway obstruction due to foreign bodies, blood clots, hematomas, or glossoptosis secondary to mandibular fractures. Combined with pharyngo-esophageal lesions, these injuries contribute to mortality rates of up to 20% in some studies.

Neurological injuries, including those to the facial (VII) and hypoglossal (XII) nerves, as well as the cervical and brachial plexuses, are not typically life-threatening but can lead to severe functional impairments.

Initial Assessment

During the initial clinical assessment of penetrating neck injuries (PNIs), findings are traditionally categorized into "hard" and "soft" signs of injury, which assist in determining the severity and type of trauma sustained (Sperry et al., 2013). Hard signs are indicative of significant injuries involving the airway, vascular structures, or digestive tract. These signs include compromised airway, visible air bubbling through the wound, active hemorrhage, an expanding or pulsatile hematoma, shock, and neurological deficits.

Soft signs, while not as definitive, provide additional clues to potential injury. These signs include, but are not limited to, extensive subcutaneous emphysema or air bubbling through the wound, proximity of the wound to the carotid artery or jugular vein, airway compromise, non-expanding hematoma, changes in voice or hoarseness, dysphagia, palpable crepitus, upper extremity pulse deficits, hematemesis, hemoptysis, and non-pulsatile bleeding.

Although hard signs are present in fewer than 10% of patients with PNI, their diagnostic value is significant, as they are highly specific for severe injuries. The presence of hard signs has a positive predictive value of nearly 90% for identifying vascular or aero-digestive tract injuries, underscoring their importance in clinical evaluation (Inaba et al., 2012).

Catastrophic Hemorrhage

Uncontrolled hemorrhage remains a leading cause of morbidity and mortality in trauma cases, with a significant portion of fatalities occurring in the pre-hospital setting (van Oostendorp et al., 2016). Injuries to the neck are categorized as junctional wounds, for which tourniquet application is not feasible. Historically, treatment relied on simple gauze dressings and direct pressure. However, advancements in medical technology have led to the development of hemostatic dressings, which enhance coagulation and facilitate hemostasis. These dressings have demonstrated effectiveness in achieving hemostasis in pre-hospital environments in 67–100% of cases, with a median success rate of 90.5% (Boulton et al., 2018).

Various hemostatic dressings are now available, including QuickClot® Combat Gauze™, predominantly used by the US military, and Celox™-coated gauze, favored in the UK. Both have been shown to arrest hemorrhage significantly more effectively than standard gauze, achieving success rates exceeding 88% and without associated adverse effects (Leonard et al., 2016).

The application of hemostatic gauze in penetrating neck injuries (PNIs) involves packing the material tightly into the wound. Any remaining gauze can then be used to cover the wound externally. Direct pressure should be maintained for at least three minutes, after which an additional dressing should be applied to sustain pressure. The gauze should remain in place until the patient reaches a secure environment. While controlling catastrophic hemorrhage is the primary concern in PNI, clinicians must balance continuous pressure against the risk of inducing cerebral ischemia due to restricted blood flow.

Airway Control and Ventilation

Managing the airway in PNI is inherently challenging due to factors such as injury-related complications, blood or secretions obstructing the airway, or secondary distortion caused by soft tissue swelling or hematoma formation. The bleeding upper airway presents unique challenges, including reduced efficiency in preoxygenation and denitrogenation, hypovolemia with imminent or established circulatory collapse, and stress-induced human factors impacting the clinical team (Kristensen & McGuire, 2020).

Given the variability in presentations, no universal consensus exists regarding airway management in PNI. Consequently, airway control decisions should be made on a case-by-case basis. Indications for intubation include airway compromise or injury, apnea or respiratory failure, hypoxia, and reduced consciousness levels. Early identification of these indications is essential in both pre-hospital settings and PNI, especially when these factors overlap.

In general, maintaining spontaneous ventilation is preferred in acute adult airway trauma patients. For agitated, time-critical patients, Rapid Sequence Intubation (RSI) is the recommended first-line intervention, albeit with specific modifications. These include minimizing or avoiding cricoid pressure and intermittent positive pressure ventilation using facemasks or supraglottic airway devices whenever possible.

Rapid Sequence Intubation

Airway management options in pre-hospital settings are inherently limited compared to hospital environments due to resource constraints. While research in pre-hospital airway management is sparse, extrapolation from emergency department data offers guidance. Mandavia et al. retrospectively analyzed 748 emergency department intubations involving PNI over three years, revealing that 11% required emergency airway control. Among these, 67.2% were intubated using RSI with direct laryngoscopy, achieving a 100% success rate. These findings align with a prior retrospective review of 107 PNI patients, which demonstrated no significant difference in success rates between advanced airway techniques like awake fiberoptic intubation and RSI with direct laryngoscopy.

Recent reviews have identified RSI as the preferred intubation method for PNI patients. Hospital data strongly support the efficacy of RSI with direct laryngoscopy in emergency intubations. Although pre-hospital RSI presents additional challenges, clinicians should prioritize immediate airway control when indicated.

The increasing adoption of video laryngoscopy (VL) in both hospital and pre-hospital settings, accelerated by the COVID-19 pandemic, has introduced additional options for airway management. According to a recent Cochrane review, VL may reduce the rate of failed intubations, particularly in cases involving difficult airways (Lewis et al., 2016). However, no evidence specifically compares VL with direct laryngoscopy (DL) for pre-hospital PNI management. Potential challenges, such as blood obscuring the VL image, must be weighed against the reported benefits until further subspecialty research is conducted and local guidelines are established.

A prospective observational study conducted by the Swiss Air Rescue Helicopter Emergency Medical Service (HEMS) reported an overall first-pass success (FPS) rate of 87.6% for VL intubations over one year, including an FPS rate of 84.8% in trauma cases (Knapp et al., 2021). Notably, airway management performed indoors or inside ambulances yielded significantly higher FPS rates (91.1%) compared to outdoor environments. This difference may reflect VL-specific benefits, such as reduced glare and improved image clarity in enclosed spaces. Nonetheless, the choice of an indoor location must be balanced against the advantages of unrestricted 360-degree access to the patient in open environments.

Ultimately, operator preference and familiarity with intubation techniques are critical. In the absence of compelling evidence favoring a particular method, personal expertise and comfort should continue to guide RSI technique selection.

Front of Neck Access

In the event that intubation attempts are unsuccessful, a "cannot intubate, cannot ventilate" scenario necessitates the consideration of Front of Neck Access (FONA). Evidence supporting this intervention in the pre-hospital penetrating neck injury (PNI) population is encouraging. A large prospective observational study conducted in combat hospitals across Iraq and Afghanistan reported 34 cases of cricothyrotomy performed pre-hospital or during transport, representing an incidence of 1.76% among 1927 patients. Of these, 83% had severe head, face, or neck injuries. The success rate for these procedures was 82% (28 cases), all of which were performed by non-physicians, highlighting the importance of operator training, competency, and familiarity over professional background. This success rate is slightly lower than the 90.5% documented in a prior meta-analysis likely attributable to the more severe injury profiles and anatomical disruption in military patients.

Conversely, a 20-year retrospective analysis of London Helicopter Emergency Medical Services (HEMS) reported a lower incidence of cricothyrotomy at 0.19% (72 out of 37,725 cases) but a higher success rate of 97%(Aziz et al., 2021). Among these, only 8 cases (10.3%) involved penetrating trauma to any anatomical region.

An alternative technique mentioned in the literature for situations where definitive airway control is unattainable involves utilizing a bougie to facilitate intubation directly through a tracheal laceration or puncture.

Ventilation

Once airway control is established and ventilation initiated, it is crucial to monitor for chest complications arising from the initial trauma or the application of positive pressure ventilation. This is particularly relevant in cases involving Zone 1 injuries with a downward trajectory of penetration. Haemothorax and pneumothorax are significant contributors to respiratory failure in PNI. In an Israeli military review spanning two decades, 2% of isolated neck injuries required chest decompression(Tsur et al., 2021).

Circulation

In PNI management, circulatory resuscitation primarily focuses on haemorrhage control, haemostatic volume resuscitation, and the prevention of trauma-induced coagulopathy. While haemostatic resuscitation techniques fall outside the scope of this discussion, we highlight measures specific to PNI haemorrhage control.

The utility of haemostatic dressings has been discussed previously. In addition, devices such as the iTClamp® have demonstrated efficacy in managing haemorrhage from open wounds in compressible zones. A case series of 10 patients with mixed arterial and venous bleeding reported 90% haemorrhage control using the iTClamp®, which increased to 100% when combined with haemostatic gauze(Filips et al., 2013; Tan et al., 2016). The device has been endorsed by the American Committee on Tactical Combat-Casualty Care as a primary intervention for haemorrhage control in PNI(Onifer et al., 2019).

Foley catheters also offer a viable option for haemorrhage control in PNI. A military case series involving 11 patients showed a 91% success rate when Foley catheters were used, with 10 mL of volume typically sufficient to arrest bleeding without compromising surrounding microcirculation(Jose et al., 2019).

In cases of traumatic cardiac arrest caused by PNI, guidelines from the Western Trauma Association recommend resuscitative thoracotomy (RT) in patients with less than five minutes of cardiopulmonary resuscitation (CPR) and profound refractory shock(Burlew et al., 2012). RT facilitates the identification and mitigation of haemorrhage sources and enables aortic cross-clamping to enhance cerebral and cardiac perfusion. A U.S. trauma center review spanning 26 years reported survival in 11% of 27 patients who underwent RT for non-torso injuries, two of whom had sustained PNI.

Thus, adjunctive measures such as the iTClamp® or Foley catheter should be considered alongside local guidelines for haemostatic resuscitation. In indicated cases, resuscitative thoracotomy remains a viable option.

Disability Prevention

Neurological injuries in PNI occur in approximately 7% of cases, with the incidence dropping to 1.5% for stab wounds(Lustenberger et al., 2011). These injuries are often associated with severe focal neurological deficits or altered mental status. Retrospective reviews have linked cervical spine immobilization in PNI with increased mortality. For example, one study found an odds ratio of 2.06 for death in patients undergoing spinal stabilization compared to those without, with a number needed to treat (NNT) of 1032 and a number needed to harm (NNH) of 66(Haut et al., 2010).

Unstable cervical spine injuries are exceedingly rare in PNI, with a review of British military casualties revealing that only 1.8% of survivors with ballistic injuries required surgical stabilization. Furthermore, c-spine collars may obscure signs of life-threatening conditions, such as tracheal deviation, subcutaneous emphysema, expanding hematoma, or absent carotid pulses.

Based on these findings, updated guidelines strongly recommend against routine spinal immobilization in isolated penetrating injuries(Maschmann et al., 2019). Instead, neuroprotective measures, such as avoiding hypoxia, hypercapnia, and hypotension, should be prioritized to prevent secondary neurological injuries.

Penetrating neck injury (PNI) is an infrequent yet complex clinical scenario encountered by pre-hospital care teams. The existing body of evidence in this domain predominantly consists of case series, with only one meta-analysis and one randomized controlled trial identified. Given the challenges of conducting prospective randomized controlled trials in this area, the development and application of an expert consensus statement derived from the highest-quality available evidence is essential for guiding clinical practice. Utilizing a shared, structured mental model, including the nuanced strategies highlighted in this review, may facilitate swift assessment and management of these injuries before transferring patients to a trauma center for definitive care. Based on the findings of this literature review, a proposed management algorithm for pre-hospital PNI management has been developed.

Interventions routinely used in the pre-hospital setting, such as rapid sequence induction (RSI) for definitive airway management, should remain standard practice, as should fundamental haemorrhage control measures like direct pressure with haemostatic gauze. Cervical spine immobilization should be avoided in all PNI cases unless there is clear evidence of severe focal neurological deficits or altered mental status.

Future research efforts in this area should aim to refine best practices within the proposed model by generating higher levels of evidence than those currently available. Specific areas of focus may include comparing the efficacy of direct laryngoscopy versus video laryngoscopy in PNI management and evaluating the relative effectiveness of various haemostatic gauze types and other immediate haemorrhage control techniques. Additionally, the impact of these interventions on mitigating secondary brain injuries warrants further investigation.

Conclusion

Penetrating neck injuries (PNIs) represent a significant challenge for pre-hospital clinical teams, requiring swift and evidence-informed decision-making. This review highlights the limited but valuable evidence base, including case series, one meta-analysis, and one randomized controlled trial, and emphasizes the importance of expert consensus in guiding clinical practice. The proposed management algorithm synthesizes current knowledge and provides a structured approach to assessment and intervention in pre-hospital environments.

Key interventions such as rapid sequence intubation (RSI) for airway management, the application of hemostatic gauze for hemorrhage control, and the judicious avoidance of cervical spine immobilization unless warranted by severe neurological deficits are reaffirmed. Future research should focus on refining these practices, particularly comparing intubation techniques, evaluating different hemostatic agents, and exploring the impact of interventions on secondary brain injury.

Incorporating a shared, structured mental model into clinical protocols may enhance the rapid and effective management of PNIs, reducing mortality and morbidity and improving patient outcomes during transfer to definitive care. This framework is a step towards standardized pre-hospital care for a complex and life-threatening condition.

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