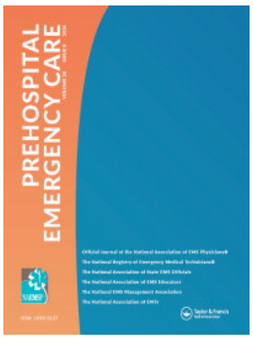

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# Prehospital Trauma Compendium: Traumatic Pneumothorax Care – a position statement and resource document of NAEMSP

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**ABSTRACT**

Emergency Medical Services (EMS) clinicians manage patients with traumatic pneumothoraces. These may be simple pneumothoraces that are less clinically impactful, or tension pneumothoraces that disturb perfusion, lead to shock, and impart significant risk for morbidity and mortality. Needle thoracostomy is the most common EMS treatment of tension pneumothorax, but despite the potentially life-saving value of needle thoracostomy, reports indicate frequent misapplication of the procedure as well as low rates of successful decompression. This has led some to question the value of prehospital needle thoracostomy and has prompted consideration of alternative approaches to management (e.g., simple thoracostomy, tube thoracostomy). EMS clinicians must determine when pleural decompression is indicated and optimize the safety and effectiveness of the procedure. Further, there is also ambiguity regarding EMS management of open pneumothoraces. To provide evidence-based guidance on the management of traumatic pneumothoraces in the EMS setting, NAEMSP performed a structured literature review and developed the following recommendations supported by the evidence summarized in the accompanying resource document.

NAEMSP recommends:

- EMS identification of a tension pneumothorax must be guided by a combination of risk factors and physical findings, which may be augmented by diagnostic technologies.
- EMS clinicians should recognize the differences in the clinical presentation of a tension pneumothorax in spontaneously breathing patients and in patients receiving positive pressure ventilation.
- EMS clinicians should not perform pleural decompression in patients with simple pneumothoraces but should perform pleural decompression in patients with tension pneumothorax, if within the clinician's scope of practice.

- When within scope of practice, EMS clinicians should use needle thoracostomy as the primary strategy for pleural decompression of tension pneumothorax in most cases. EMS clinicians should take a patient-individualized approach to performing needle thoracostomy, influenced by factors known to impact chest wall thickness and risk for iatrogenic injury.

- Simple thoracostomy and tube thoracostomy may be used by highly trained EMS clinicians in select clinical settings with appropriate medical oversight and quality assurance.

- EMS systems must investigate and adopt strategies to confirm successful pleural decompression at the time thoracostomy is performed.

- Pleural decompression should be performed for patients with traumatic out-of-hospital circulatory arrest (TOHCA) if there are clinical signs of tension pneumothorax or suspicion thereof due to significant thoraco-abdominal trauma. Empiric bilateral decompression, however, is not routinely indicated in the absence of such findings.

- EMS clinicians should not routinely perform pleural decompression of suspected or confirmed simple pneumothorax prior to air-medical transport in most situations.

- EMS clinicians may consider placement of a vented chest seal in spontaneously breathing patients with open pneumothoraces.

- In patients receiving positive pressure ventilation who have open pneumothoraces, chest seals may be harmful and are not recommended.

- EMS physicians play an important role in developing curricula and leading quality management programs to both ensure that EMS clinicians are properly trained in the recognition and management of

tension pneumothorax and to ensure that interventions for tension pneumothorax are performed appropriately, safely, and effectively.

**Keywords:** EMS, pneumothorax, thoracostomy, trauma

## INTRODUCTION

Emergency Medical Services (EMS) clinicians encounter patients with pneumothorax from blunt and penetrating trauma in up to 20% of major trauma victims found alive and pleural decompression of tension pneumothorax (TPTX) can be lifesaving (1-9). Multiple interventions with varying risks and potential benefits are available to EMS clinicians for the treatment of open and tension pneumothorax in adult and pediatric patients. These include pleural decompression via needle thoracostomy (NT) (a.k.a. needle decompression), simple thoracostomy (ST) (a.k.a. “Finger” or “Open” thoracostomy), tube thoracostomy (TT) (a.k.a. “chest tube,” “chest drain,” “pleural drain,” or “intercostal catheter/drain”), and chest seals for open pneumothorax (5, 10-12). Tension pneumothorax is challenging to detect in the field and difficult to differentiate from other causes of traumatic shock, including hemorrhage, pericardial tamponade, and neurogenic shock. There are currently varied EMS practices in identification of TPTX, preferred approach to thoracostomy; and confirmation of successful pleural decompression (5, 11). We performed a structured literature review and developed evidence-informed recommendations to guide EMS clinicians in the evaluation and treatment of traumatic pneumothorax, and to provide guidance to EMS systems regarding the education and quality improvement practices necessary to maintain EMS clinician competency.

**METHODS**

Ten topic areas of importance were identified through consensus (Table 1). A PubMed search was performed in March 2023 for all existing literature following preestablished NAEMSP trauma compendium methodology and using additional terms relevant to EMS detection and treatment of pneumothorax (Table 2) (13). The lead author (JWL) screened titles and excluded duplicates and papers that were not relevant to the study population, clinical environment, or interventions in question. The author team then screened abstracts (AB:29, RD:31, KI :30, JWL:131, MM:32, CW:31) and further excluded articles if not in scope. Question regarding inclusion/exclusion were brought to the group for consensus. Authors then performed full text reviews (AB:29, RD:24, KI:30, JWL:125, MM:29, CW:23) with articles that addressed one or more of the ten topic areas retained. Publications that were unclear were brought to the lead author for discussion, with a general approach to retaining literature that applied directly or indirectly. To identify articles that may have been missed by the primary search, a snowball search of references lists from retained papers was performed. Wherever possible, our review focused on literature specific to the prehospital setting and interventions performed by EMS clinicians, including paramedics, EMS-based nurses, and EMS physicians. Where EMS-based literature was lacking, hospital-based literature was included to more thoroughly inform recommendations.

Authors catalogued the retained articles according to the pre-defined topic areas, with articles addressing multiple topic areas included in all relevant content review. Papers were subcategorized if they addressed treatment-related iatrogenic injuries or complications, or specifically addressed pediatric patients. The authors used a pre-established abstraction form to summarize the articles that were included in the final evidence library. Finally, the evidence was synthesized to develop the position statement recommendations.

**RESULTS**

Figure 1 illustrates the literature review strategy, including an accounting of how many articles were categorized into each of the 10 primary topic areas, as well as secondary topic categorization for epidemiology, anatomic site, pediatrics, and complications. Of 275 articles in the final evidence library there were 119 retrospective observational reviews of case series or trauma registries; 36 case reports; 28 prospective observational, technical, or clinical trials; 16 technical descriptions or models; 15 published guidelines or updates; 14 non-systematic reviews of prior literature;13 systematic reviews or meta-analysis; 11 randomized controlled trials, 4 of which were swine studies; 10 descriptive educational studies, 8 correspondence, 3 surveys; 1 textbook chapter; and 1 methodology paper. Several articles provided evidence that informed multiple areas of focus within this manuscript. The evidence regarding the ten topic focus areas is summarized in the following supplemental tables:

Supplemental File Table A – EMS Identification of pneumothorax (1, 12, 14-39)

Supplemental File Table B – Point of Care Ultrasound detection of pneumothorax (22, 40-77)

Supplemental File Table C – Needle Thoracostomy (2, 7, 10-12, 14, 22, 24, 27, 38, 45, 46, 50, 55, 66, 69, 72, 78-179)

Supplemental File Table D – Simple Thoracostomy (82, 89, 109, 116, 119, 124, 141, 155, 156, 165, 180-196)

Supplemental File Table E – Tube Thoracostomy (12, 24, 38, 65, 88, 89, 104, 106, 109, 124, 126, 134, 155, 158, 163, 164, 180-182, 187, 190, 191, 196-226)

Supplemental File Table F – Measures of successful decompression (2, 137, 144-146, 175, 187, 214, 227)

Supplemental File Table G – Chest seals and open pneumothorax (96, 132, 228-234)

Supplemental File Table H – Pleural decompression and Traumatic Out of Hospital Circulatory Arrest (81-83, 185, 189, 208, 219, 235-237)

Supplemental File Table I – Air Medical Transport considerations for patients with pneumothorax (237-243)

Supplemental File Table J – Education of EMS clinicians in pneumothorax evaluation and management (27, 50, 57, 63, 67, 92, 105, 108, 113, 161, 163, 168, 193, 201, 211, 244)

## DISCUSSION

### Diagnosis

***EMS identification of a tension pneumothorax must be guided by a combination of risk factors and physical findings, which may be augmented by diagnostic technologies.***

The goal for EMS clinicians is to identify TPTX, not every simple pneumothorax. Accurate field diagnosis of TPTX is critical to realize patient benefit and to avoid harm from unnecessary interventions. Unfortunately, 18-42% of patients receiving pleural decompression by EMS do not have any pneumothorax on ED CT imaging (131, 145, 156).

Pneumothorax can result from a variety of injury mechanisms, but almost always occurs in conjunction with serious injuries to other body regions, especially in victims of blunt trauma (1, 3-5, 9, 245). Proper use of injury reduction technology has a protective effect, as patients injured in traffic collisions restrained by safety belts and airbags together typically sustain less severe chest trauma and require less pleural decompression compared to patients restrained by air bags alone(36). These factors should be carefully considered by EMS clinicians when forming a differential diagnosis for shock that includes tension pneumothorax.

Lung auscultation may help with diagnosis of pneumothorax and guide therapeutic intervention (38). If the pneumothorax is large and clinically relevant, auscultation of unilateral decreased breath sounds alone was shown to be 93-98% specific (PPV 86-97%) for ipsilateral pneumothorax. However, auscultation for asymmetric lung sounds lacks sensitivity to be used as a single diagnostic criterion to detect TPTX. In many cases, the noisy, chaotic prehospital environment makes auscultation particularly challenging. Further, in intubated patients,

asymmetric breath sounds can lead to false-positive findings if bronchial intubation has occurred (154, 246). Unilateral decreased or absent breath sounds may also indicate presence of other injuries, such as gastrothorax, in which pleural decompression is contraindicated (26, 30, 34, 149, 178, 247-250). Bilateral pneumothorax may also complicate accurate, timely recognition of TPTX.

Measurement of respiratory rate and quality can guide detection of pneumothorax; failure to recognize tachypnea is shown to result in under-triage of patients with blunt thoracic injury (39). However, it is not possible to assess spontaneous respiratory rate in artificially ventilated patients. Importantly, combining the findings of symmetric breath sounds, normal respiratory rate, and absence of dyspnea suggests strongly *against* the presence of pneumothorax (38).

Some authors have suggested the need for augmentation of the physical assessment with Point-of-care ultrasound (POCUS) (156). Most EMS-based studies of POCUS detection of pneumothorax evaluate helicopter-based EMS clinicians, including paramedics, nurses, and EMS physicians. This evidence is augmented by inclusion of literature from hospital-based environments. In aggregate, this body of evidence shows that POCUS is superior to plain chest radiography in detecting pneumothorax (40, 51, 53, 68-70, 73, 75). Further, a systematic review and metanalysis found that EMS-POCUS was highly specific (99%) but poorly sensitive (61%) compared to ED POCUS (99% specific, 85% sensitive) (53). Importantly, detection of pneumothorax using POCUS is dependent on the skill and experience of the operator. Real-time transmission of POCUS images to clinical specialists for interpretation and artificial intelligence technologies show promise in improving the accuracy of EMS-POCUS to diagnose pneumothorax (22). While EMS-POCUS can be a helpful diagnostic tool, it must be interpreted in the clinical context of other exam findings; POCUS identification of a pneumothorax alone does not signify need for pleural decompression. Notably, POCUS can identify PTX as small as 18mL, and PTX volumes up to 378mL have

been shown to be tolerated without significant clinical effects (38). Pragmatically, EMS-POCUS may be most useful in excluding the presence of pneumothorax and helping reduce unnecessary interventions (45, 72, 120, 186, 194). Emergency Medical Services agencies that use POCUS must provide appropriate training and quality oversight to ensure its use is appropriate and effective.

***EMS clinicians should recognize the differences in the clinical presentation of a tension pneumothorax in spontaneously breathing patients and in patients receiving positive pressure ventilation.***

A critical finding of Roberts et al, who developed the first systematic description of TPTX, and also supported by Leigh-Smith et al, is the important differences in TPTX development in spontaneously breathing vs artificially ventilated patients (12, 31, 32). Their observations are summarized in Table 3. Most notably these papers report that hypotension was 12.6 times more likely in ventilated patients, with 70.4% of these patients experiencing hypotension and cardiac arrest within minutes of initial presentation. The increased adjusted hazard for mortality in ventilated patients was 17.7 times that of spontaneously breathing patients. Hypotension and subcutaneous emphysema were also independently associated with pneumothorax patients receiving artificial ventilation (31, 32). Unlike presence of hypotension, presence of tracheal deviation and jugular venous distension as markers of TPTX appear to be exaggerated (32). However tracheal deviation can be a *late* sign of tension pneumothorax in spontaneously breathing patients (5, 12, 31, 32).



**Treatment**

***EMS clinicians should not perform pleural decompression in patients with simple pneumothoraces but should perform pleural decompression in patients with tension pneumothorax, if within the clinician's scope of practice.***

Pleural decompression by EMS clinicians is only recommended when TPTX is present, as evidenced by objective findings paired with shock of unknown cause, sudden loss of cardiac output, or traumatic arrest (95, 109, 187). Emergency Medical Services clinicians should not perform decompression for simple pneumothorax in hemodynamically stable patients (181). Table 4 provides further criteria to guide decision making for performing pleural decompression.



**Needle Thoracostomy**

***When within scope of practice, EMS clinicians should use needle thoracostomy as the primary strategy for pleural decompression of tension pneumothorax in most cases. EMS clinicians should take a patient-individualized approach to performing needle thoracostomy, influenced by factors known to impact chest wall thickness and risk for iatrogenic injury.***

Needle thoracostomy is the most common decompression technique performed by EMS clinicians, occurring in up to 5% of trauma cases, but only 0.03% of pediatric trauma cases (93, 97). Performed correctly, NT can decrease the odds of 24-hour mortality by up to 25% (142). However, up to 30-94% of NT attempts fail to breach the pleural space or are malpositioned (2, 85, 131, 251). Further, 12-42% of EMS NTs are performed unnecessarily (106, 156). The clinical utility of NT in the current EMS setting is limited by the need to improve both the accuracy of TPTX identification and the frequency of procedural success.

*Risk of iatrogenic injury and complications from needle thoracostomy*

Iatrogenic injuries can occur secondary to NT, including intrathoracic vascular injuries, perforation of the myocardium, injury to the diaphragm, and lacerations to the liver and spleen, as illustrated in Figure 2 (95, 152,

174, 192, 252). Creation of iatrogenic pneumothorax is also possible if NT is performed on patients misidentified with pneumothorax (6, 107, 178). Some of this risk is acceptable for patients who have true TPTX. However, in the up to 42% of patients who undergo prehospital NT unnecessarily, the risk for severe injuries in the absence of benefit is of significant concern (106, 131, 156).

The ability of EMS clinicians to accurately identify recommended locations for NT has been questioned. Military clinicians encountered greater difficulty correctly locating the lateral NT site [4$^{th}$ or 5$^{th}$ ICS at the anterior axillary line (4/5ICS AAL)] compared to the anterior NT site [2$^{nd}$ intercostal space midclavicular line (2ICS MCL)] (157). Civilian paramedics' success in identifying the anterior location is also variable (28% within 2cm of the correct site, 86% within 5cm of the correct site) (27, 108). Physicians are not infallible, with studies showing a 20-40% malposition rate of NTs including placement outside of the 2ICS or 1-2cm away from (usually medial to) the MCL (118, 253).

Risk of iatrogenic injury and unsuccessful decompression with NT is impacted by anatomic site, patient age, insertion technique, and device length. There is significant risk for cardiac injury when using a left lateral approach for NT in all ages (100, 135, 173). Increased arterial tortuosity in the elderly and narrower ICS in pediatric patients also increases the risk for injury to intercostal vessels, emphasizing the need to insert the NT device as close to the superior edge of the rib as possible (98, 169). Several studies found that needles <6cm would fail to cross the chest wall in adults (46, 125). Although several resources recommend use of NT devices between 5-8cm, devices >7cm have been associated with an increased risk of iatrogenic injury with no added benefit improving successful decompression (46, 79, 95, 125, 127, 156, 158, 170). Pediatric patients are at increased risk for iatrogenic injury if devices longer than 3.8cm are used for NT(135).

*Anatomic factors related to successful needle thoracostomy*

Multiple publications address the concept of "best" anatomical locations for NT, using either an anterior or lateral approach. However, use of a "one-site-suits-all" approach fails to account for the myriad patient-specific factors that impact chest wall thickness or the proximity of adjacent structures that could be injured during NT attempts. Multiple factors impact success of NT including patient anatomy, technique, and device characteristics.

In general, adult females have greater chest wall thickness (CWT) then males when considering an anterior approach whereas the difference is much less with a lateral approach (80, 111, 157, 179). However, these differences may be less pronounced in healthy 18-40-year-olds with a BMI <30 (7, 121). Importantly, the chest wall is notably thinner with the arms positioned above the head versus an arms-down position (179). Overlying anterior breast tissue may also obscures landmarks needed to guide a lateral NT approach, leading to slower and less accurate site identification (157). Additionally, in pregnant females at ≥20 weeks gestation the uterus causes displacement of abdominal organs and shifting of the diaphragm upward, and lateral NT and TT approaches must be adjusted superiorly from the 4$^{th}$ to the 3$^{rd}$ ICS to avoid iatrogenic injury to sub-diaphragmatic structures (89, 124, 155)

Sex-related differences in CWT may also vary based on age, as a 4.5cm catheter will fail to decompress 10% of males <40 years old and 19% of males ≥40 years old. In female patients, the expected failure risk is higher, with 33% of females <40 and 25% of females ≥40 at risk for failed pleural decompression with a 4.5cm catheter (179).

However, in males and females >75yo CWT is thinner and NT success rates are higher with anterior NT (172). Past medical history also impacts CWT, with COPD patients having thinner CWT than expected for age (172).

Failure to access the pleural space due to needle length or anatomic differences in CWT is rarely an issue in children less than 13 years old, in whom there is little variation in CWT (55, 135). Several authors found that the strongest predictor of pediatric CWT was patient weight (135, 169). Mandt advocated for use of a 3.8cm 14g or 16g NT device for children < 13 yo (or who fit on a length-based resuscitation tape) and noted that the ATLS-recommended minimum 5cm long device for adult NT is twice the CWT of most children (84, 135).

Multiple retrospective reviews have investigated the impact of BMI and weight on CWT(112, 126, 254). While CWT is noted to increase for both anterior and lateral NT sites as BMI increases, the anterior NT site appears most affected (255). Failure to reach the pleural space with NT or tube thoracostomy (TT) was significantly correlated with BMI using an anterior approach (25% in the underweight group, 46% normal weight, 78% overweight, 92.9% in the obese group) (150)

*Device characteristics necessary for successful needle thoracostomy*

Most recent studies advocate for NT devices to be at least 6.5cm for adults and no longer than 3.8cm for pediatric patients (87, 99, 103, 135, 150, 167). Kinking and occlusion of flexible NT catheters is an issue, especially with lateral NT when the patient's arm is packaged against the NT catheter (6, 91, 178). To mitigate kinking, rigid NT devices have been developed. However, sharp-tipped rigid devices introduce laceration risk to internal structures. To mitigate this, some NT devices (aka Veress needles) have blunt tips that retract to allow the sharp tip to incise the chest wall and then extend to cover the needle tip once it passes into the pleural

cavity (151, 256, 257). Although several papers describe such devices, our review identified only one paper that discussed how these device modifications impact the risk for iatrogenic injury from NT (133, 151, 153, 256, 258).

*Needle thoracostomy technique*

Radiographic assessment of CWT may overestimate actual NT success when technique is considered (156). Perpendicular insertion minimizes the CWT that must be traversed and may also reduce the risk for iatrogenic injury as illustrated in Figure 2 (100) To prevent failed pleural decompression due to CWT exceeding the length of the NT device, Tactical Combat Casualty Care (TCCC) recommends routinely inserting NT devices to their maximal depth, known as "hubbing the needle" (95). But, "hubbing" may dangerously increase the risk of iatrogenic injury with NT devices longer than 7cm (7). Importantly, TCCC guidelines are intended to guide care for healthy young soldiers and may not be generalizable to the civilian population.

Several NT verification techniques are available in the EMS setting. EMS clinicians may use POCUS to determine the required depth to safely and consistently decompress TPTX and to verify successful decompression. This has been demonstrated in pediatric patients in the EMS setting (55, 169). In adults, while described in hospital-based settings, this approach has received only limited field evaluation in pilot studies (50, 64, 66). Performing NT using a needle aspiration technique by employing a saline-filled syringe attached to the NT device can help limit the depth the needle penetrates thus reducing risk of injury to deeper structures (7, 137). Although needle aspiration and POCUS-guided NT are promising methods to verify successful NT and reduce risk for iatrogenic injury, more research is needed to confirm the utility of these techniques in the EMS setting. Table 5 summarizes the various patient-based, device-based, and technique-based factors that should be considered to optimize safe and successful access to the pleural cavity.

**Simple and Tube Thoracostomy**

***Simple thoracostomy and tube thoracostomy may be used by highly trained EMS clinicians in select clinical settings with appropriate medical oversight and quality assurance.***

Much of the EMS simple thoracostomy (ST) (aka: finger or open thoracostomy) literature is from Europe and Australia, where EMS physicians commonly deliver prehospital care. Caution must be taken in extrapolating that evidence to U.S. EMS systems. Simple thoracostomy provides more reliable pleural decompression than NT in the ED (109). However, there is insufficient evidence that ST is procedurally and clinically superior to NT in the EMS setting (116, 156, 165, 188, 189, 194). Up to 10.6% of EMS STs develop a complication, including iatrogenic injuries, failure to access the pleural space, or missed or recurrent pneumothorax; a complication rate that highlights the technically complex nature of the procedure (194). In a physician-based EMS service, complication rates were similar to those encountered with tube thoracostomy (TT) performed in the emergency department (180). Other authors found lower complication rates and higher success with ST performed by EMS physicians compared to NT (141, 180, 186, 191). Successful introduction of ST in EMS clinician scope of practice must consider the greater technical complexity and resource requirements of ST relative to NT. Further, ST requires robust quality management programs to ensure STs are performed safely and effectively. These complexities may change the risk-benefit calculus for EMS agencies working to determine appropriate scope of practice for their clinicians.

Tube thoracostomy is the most procedurally complex thoracostomy technique and is associated with significant risk of complications. Tube thoracostomy performed by HEMS-based EMS clinicians show higher rates of clinical improvement (75% overall, 60% improved vitals) compared to NT (60% overall, 32% improved vitals), but HEMS TT misplacement rates are reported up to 22% (88, 104, 214, 223). Other studies found similar complication

rates of TT performed by EMS physicians and paramedics compared with hospital-based physicians (206, 222, 226). Even so, in hospital settings, up to 30% of TTs are misplaced or associated with major organ injury, which may be dependent on the experience of the clinician and technique. Trochar-based placement is implicated in 30% of cases of TT malposition (181, 204, 217, 218). While TT may be performed by highly trained EMS clinicians in select clinical settings, ST may be more appropriate for most agencies.

For EMS systems who integrate TT, procedural technique can reduce risk of injury. While EMS trochar-based TT is not recommended, use of sharp-tipped trocars is especially discouraged. Incision of the chest wall with blunt dissection of the intercostal tissues and digital exploration of chest provides a more reliable confirmation that the pleural cavity has been breached and eliminates the risks of iatrogenic injury caused by trocars (203, 209, 217, 218). Ultrasound-guided TT placement has also been suggested to help improve the effectiveness and reduce the risks associated with TT in the EMS setting, but is a procedurally more complex approach (65).

For pediatric patients with TPTX, Quinn et al identified a 30% failure rate of prehospital NT and advocate for TT in this population (259). However, this does not take into account that the width of the 4th ICS in pediatric patients < 10 yo is typically less than 1cm, too narrow to insert a finger in the ICS during traditional ST or TT without significant risk for iatrogenic injury of intercostal vessels and nerves (169). Given these issues, use of ST in patients < 10 yo is not recommended, leaving instrument-based TT as the single alternative to NT for pleural decompression in this age group. Agencies choosing to incorporate adult and pediatric TT over NT or ST must consider the additional investments needed to attain and maintain this skill.

**Risks for Occupational Injuries**

Our review did not identify any publications that discussed occupational injuries sustained by EMS clinicians when performing pleural decompression. We believe this is due to under-reporting rather than true absence of sustained injuries. The use of scalpels and finger insertion during ST and TT increase the risk for potentially significant occupational exposures, particularly if performed during patient transport. Needle thoracostomy likely carries far lower risk of occupational injury, especially if sharps-related safety procedures are strictly followed. These occupational risks should be carefully considered as EMS agencies consider their preferred approach for thoracostomy.

**Confirming successful pleural decompression**

***EMS systems must investigate and adopt strategies to confirm successful pleural decompression at the time thoracostomy is performed.***

Various measures of success have been suggested including listening for a "rush of air" or assessing for improved ventilation compliance or improvement of vital signs. However, an initial "rush of air" is not a reliable method to confirm proper NT placement, as air may be released from sources other than a pneumothorax as depicted in Figure 3 (109, 178). If TPTX is the singular reason for traumatic shock, successful decompression should be evident by improvement in vital signs. However, because TPTX might co-existent with hemorrhagic, neurogenic, cardiogenic, or other obstructive shock, vital signs might not improve even if decompression of TPTX was successful. Commercial tools using mechanical or chemical mechanisms to provide visual evidence of NT device entry into the pleural space have been developed, however they have undergone limited investigation in humans (143, 144, 221, 227, 256, 257). Simple thoracostomy and TT techniques that involve digital assessment for entry into the pleural space give the best real-time evidence that the pleural space has been

entered. However, misplacement of TT into the chest wall, and incomplete or failed decompression has been documented for both TT and ST. Some misplaced ST or TT might be attributed to techniques that use commercial devices or trocars to dissect through the chest wall rather than digital exploration of the chest cavity (201).

Figure 4 summarizes the aforementioned considerations into a stepwise guide for detection and treatment of suspected tension pneumothorax.

**Need for downstream intervention**

Wernick recommends placement of a definitive TT in the ED if NT is performed (178). However, given the high rate of unnecessary NTs performed by EMS and the high failure rate of EMS NT to enter the pleural space, in the hemodynamically stable patient decisions to perform ST or TT following NT should be based on radiographic evidence of true pneumothorax (106, 145, 156).

Hemodynamically unstable patients who have undergone NT should undergo either repeat NT or an ST or TT depending on the EMS clinician scope of practice. Hemodynamically unstable patients who have undergone ST should undergo a repeat finger sweep to ensure the ST properly entered the pleural space and that the ST site has not become occluded (6, 24). Unstable patients should also undergo evaluation for other causes of traumatic shock. Hemodynamically stable patients who have undergone ST in the field should undergo definitive TT in the hospital. While no published evidence exists to guide clinicians, the Royal College of Surgeons recommends using the ST incision for TT, rather than making a new incision (6, 24). This avoids unnecessary incisions and reduces risk for other complications. There is no conclusive evidence regarding prehospital use of

antibiotics following ST, but intravenous antibiotics should be administered in the ED after all definitive TT placements that follow field-based STs (6, 199).

**Suspected tension pneumothorax in traumatic out-of-hospital cardiac arrest**

***Pleural decompression should be performed for patients with traumatic out-of-hospital circulatory arrest (TOHCA) if there are clinical findings of tension pneumothorax or suspicion thereof due to significant thoraco-abdominal trauma. Empiric bilateral decompression, however, is not routinely indicated in the absence of such findings.***

Needle thoracostomy is most beneficial in trauma patients who are unstable but still have vital signs (177). In cases of traumatic out-of-hospital circulatory arrest (TOHCA) from isolated TPTX, decompression can be a lifesaving intervention. The incidence of TPTX as the cause of TOHCA varies widely in different settings, as does the impact of decompression on Return of Spontaneous Circulation (ROSC) and overall survival. (8, 9, 185, 235). In the Netherlands, 9.7% of TOCHA had TPTX (235). In one ground-based U.S. EMS system, TPTX was found in 32% of TOHCA patients (185). Smith et al found that up to 60% of fatalities in U.S. Civilian Public Mass Casualty Shooting events suffered potentially preventable deaths attributed to isolated pneumothorax (9). Much of the current literature largely represents air-based and international EMS systems where EMS physicians often play a larger role in providing in-field care, and where traumatic epidemiology may be different, making it challenging to generalize findings to U.S. EMS systems.

In one case series of 37 TOHCAs, 17 underwent ST by EMS physicians and 1 underwent NT by paramedics resulting in ROSC in 4/18 (22.2%) patients (141). All four ROSC patients had clinical signs of a TPTX but no external signs of chest injury. Despite achieving ROSC, 100% of these patients died from non-survivable head

injury within 24 hours. In a larger series of 909 TOHCAs treated with bilateral ST by EMS physicians from London HEMS, 6/909 (0.7%) achieved ROSC (191). A Houston, TX study of ST by ground paramedics for 57 blunt TOHCA patients (75% bilateral STs) showed ROSC rates approaching 25%, and neurologically intact survival of 7% (4/57) (185). An observational study of 169 TOHCAs with empiric bilateral NT by paramedics in California found no difference in mortality for penetrating vs blunt traumatic mechanisms (175). A German study of 757 TOHCA patients found that the judicious use of field-performed TT improved survival (OR 0.3) (208). Finally, although the use of trauma-based resuscitation protocols is shown to increase the frequency of EMS thoracostomy in TOHCA, this change was not associated with increase ROSC or survival to discharge (83, 219, 260). Based on this evidence, EMS patients with TOHCA with clinical signs of TPTX should undergo NT or ST, however, there is insufficient evidence to support routine empiric bilateral decompression in the absence of suspected tension pneumothorax due to thoraco-abdominal trauma, because it is unlikely to improve survival.

**Prophylactic pleural decompression**

***EMS clinicians should not routinely perform pleural decompression of suspected or confirmed simple pneumothorax prior to air-medical transport in most situations.***

Many trauma patients will be transported by helicopter-based EMS (HEMS). Concerns that a simple pneumothorax will increase in size when a patient is taken to higher altitude or that TPTX will be difficult to detect or treat in-flight have led to the belief that patients with suspected or radiographically confirmed simple pneumothorax should undergo pleural decompression, especially via TT, prior to HEMS transport. As many HEMS transported patients may also be receiving positive pressure ventilation (PPV), the aforementioned concerns are possibly amplified by a study by Heng et al, which suggested that patients with simple pneumothorax receiving positive pressure ventilation (PPV) may suddenly develop TPTX (207).

Performance of TT prior to HEMS interfacility transport has been shown to delay transport by up to 53 minutes, but, pre-transport TT and transport by HEMS have also been shown to have a potential survival benefit vs. ground transport without TT (147, 216, 243). It is not clear whether this survival benefit can be attributed to pre-transport TT or whether other advanced care and/or shorter transport times afforded by HEMS are the cause of these improved outcomes.

The size of a simulated pneumothorax can increase by 1% for every 500ft increase in altitude, with between 12.7-16.2% maximum volume increases at 5000ft above ground level, but the clinical significance of this is unclear (240). Despite this altitude-driven change, development of TPTX in flight is rare, including in patients receiving PPV, and the perceived barriers to evaluation and treatment of TPTX in flight are not significant in actual clinical practice. In an evaluation of 66 HEMS patients flown with an average altitude gain of 1890ft, only 6% (4/66) of adult trauma patents developed TPTX, and only 1/66 developed TPTX while receiving PPV (representing 1/14 of PPV patients). All 4 patients that developed TPTX were appropriately identified and successfully treated with NT in-flight (200). A review of 412 patients <18yo with known traumatic pneumothorax, including 77.4% known prior to transport, showed that despite an average altitude gain of 2,337ft no patient developed TPTX during transport (238). Although 19 patients were treated with TT after arriving at the trauma center, 15/19 of whom received PPV in flight, further review of this study suggests that these TTs were performed out of abundance of caution rather than presence of TPTX on arrival. Work by Seymour et al similarly found no evidence of TPTX in PPV patients undergoing HEMS transport (241). Other work similarly suggests that low altitude aeromedical transport alone is not an indication for tube thoracostomy (24).

**Open pneumothorax**

***EMS clinicians may consider placement of a vented chest seal in spontaneously breathing patients with open pneumothoraces.***

***In patients receiving positive pressure ventilation who have open pneumothoraces, chest seals may be harmful and are not recommended.***

Open pneumothorax occurs in only 1/10,000 major trauma patients and the need for intervention in open pneumothorax is influenced by whether the patient is spontaneously breathing (6). In spontaneously breathing patients, negative intrathoracic pressure is created with each inspiration and air from the external environment may be "sucked in" through an open pneumothorax. Use of a chest seal may prevent ingress of air through these injuries.

Positive pressure ventilation creates intrathoracic pressure that is higher than atmospheric pressure, making it unlikely that air will *ingress* through an open chest wound. In fact, placement of a chest seal in these patients may prevent *egress* of intrathoracic air, leading to development of TPTX. Therefore, chest seals are not necessary for artificially ventilated patients. These patients should be closely monitored for obstruction of chest wounds by blood or any unvented dressing, as occlusion may precipitate development of a TPTX. If occlusion occurs, any overlying dressing should be removed and NT or ST are recommended if removal of the occlusion does not decompress the TPTX (6).

Evidence in support chest seal dressings is generally lacking, however if an occlusive dressing is going to be used a vented commercial chest seal is preferred over an unvented seal (6, 96, 228, 230). If a commercial vented

chest seal is not available, the chest wound could be covered with a thin, dry, adherent dressing, but 3-sided dressings are no longer recommended (6, 96). Improvised occlusive dressings have been described, but evidence showing superiority of individual commercial or improvised devices is lacking (232, 234). Under ideal-use conditions, vented chest seals should occlude open chest wounds. However, under real-use conditions, blood or debris may prevent these dressings from properly adhering to the chest wall. Decisions regarding if and what type of chest seals to include in the EMS clinicians' kit should be based on local practice environments (132, 231, 261).

If a patient with an open pneumothorax develops a TPTX, nothing should be inserted through the chest wound, even if it overlies an accepted location for pleural decompression. Chest seals should be assessed and removed if causing occlusion. If removal of the chest seal does not decompress the TPTX, NT, or ST should be performed at an appropriate anatomic site ipsilateral to the open chest wound. Assessment for contralateral TPTX should also occur, especially when penetrating trauma may have traversed the mediastinum. If these interventions are not effective in improving vital signs, the EMS clinician should assess for other causes of shock.

**Implementation Guidance and Evaluation**

***EMS physicians play an important role in developing curricula and leading quality management programs to both ensure that EMS clinicians are properly trained in the recognition and management of tension pneumothorax and to ensure that interventions for tension pneumothorax are performed appropriately, safely, and effectively.***

Decompression of TPTX by EMS clinicians can be lifesaving and NT is probably the lowest cost, easiest to perform technique in this setting. Unfortunately, NT is often performed unnecessarily and/or ineffectively. Given

the challenges in identifying TPTX and the rarity with which an individual EMS clinician will perform NT, mechanisms to ensure both initial and ongoing competency are imperative. No conclusions could be drawn regarding best educational practices, but hands-on training using cadavers or manikins may be more effective than didactic-only training. For many, the costs of these resources may be a barrier to implementation (27, 50, 57, 63, 67, 92, 105, 108, 113, 161, 163, 168, 193, 201, 211, 244).

In the U.S., NT is currently only in scope of practice for paramedics, nurses, and EMS physicians, limiting the availability of NT to the regions served by these clinicians (262). Until advancements are made in EMS identification of TPTX and performance of NT, it is inappropriate to expand scope of practice for Advanced EMTs, EMTs, or EMRs.

To improve outcomes, curricula must be revised to focus on accurate in-field recognition of TPTX and to emphasize immediate evaluation of the clinical effectiveness of pleural decompression. Revisions should also highlight the differences in the manifestation of TPTX in ventilated and spontaneously breathing patients and other key points emphasized in this manuscript. Further gains might be realized through development of affordable, field-appropriate tools that improve TPTX detection, provide real-time confirmation of successful decompression, and/or minimize procedural risk. Though POCUS has shown promise in the management of TPTX in the HEMS setting, more research is needed to determine the utility of POCUS in other EMS settings. If supported by future evidence, broader adoption of POCUS for TPTX will require significant investment to procure equipment, train clinicians, and to perform quality assurance to ensure POCUS programs achieve goals.

Finally, more quality assurance resources must be invested to monitor and evaluate clinical performance and to measure the effect of EMS interventions on patient-based outcomes including accurate recognition of TPTX, the effectiveness of thoracostomy interventions, surveillance for thoracostomy-related complications, and other morbidity and mortality measures.

## LIMITATIONS

Our literature review and development of recommendations was limited by a paucity of direct EMS-based evidence, inconsistent reporting of outcome measures, and significant heterogeneity in clinician scope of practice across included papers. Further, our literature search strategy may have missed some articles germane to our discussion. Additionally, due to resource limitations we were unable to grade the evidence or perform a risk of bias assessment such as would be performed using GRADE methodology.

## CONCLUSIONS

Traumatic tension pneumothorax and open pneumothorax are life-threatening, high risk, low frequency events that can be mitigated by EMS clinicians when they are appropriately recognized and treated. To optimize patient outcomes, improvements must be made in the EMS clinician's ability to recognize these conditions. Further, techniques to assess for successful decompression must be employed. Importantly, we must also improve in the quality oversight of the interventions used by EMS clinicians to treat these injuries. Emergency Medical Services agencies can take steps toward improving patient outcomes by implementing the recommendations in this document.

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**Figure 1:** Literature search flow diagram

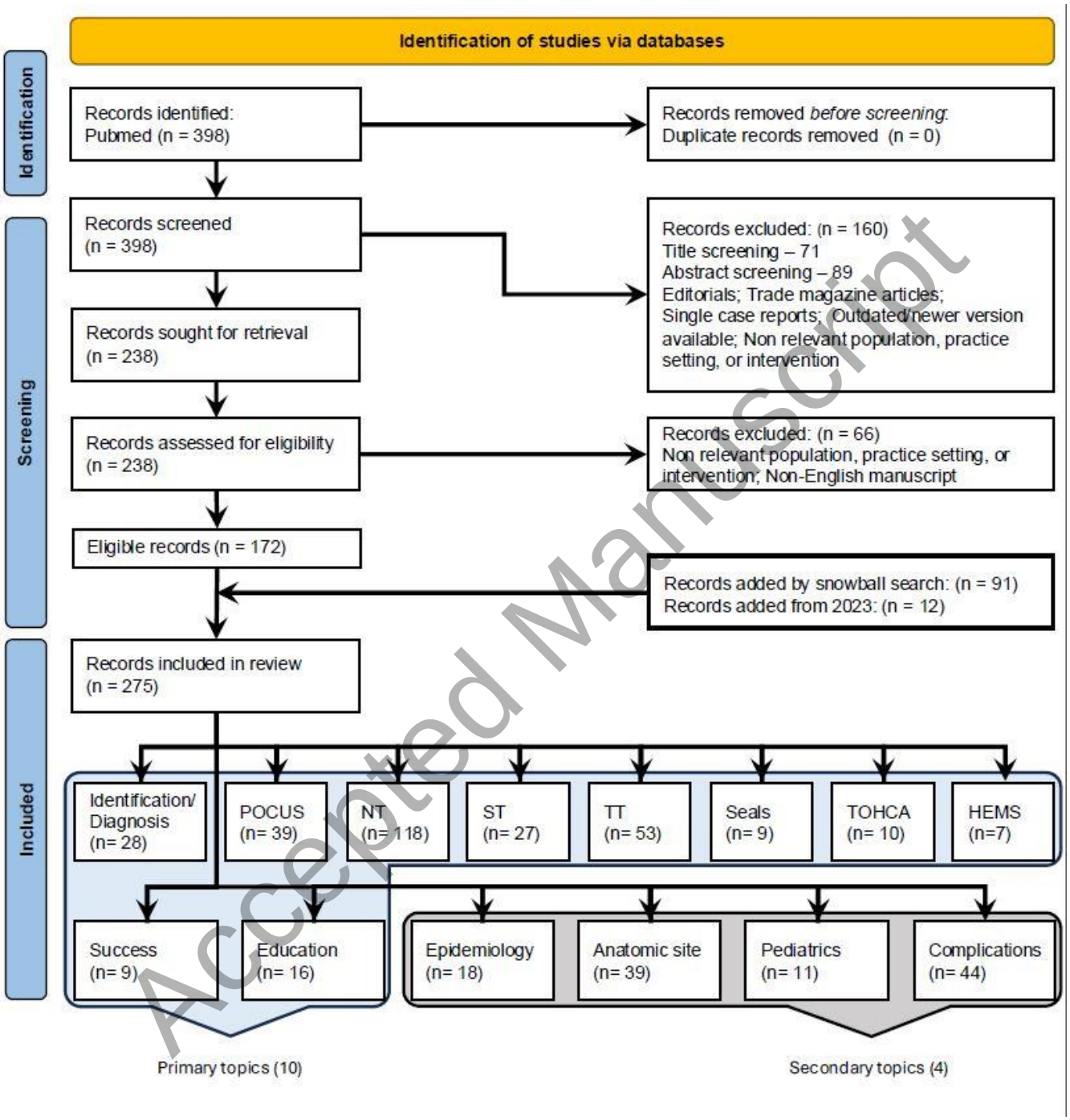




**Figure 1 footnotes:** POCUS – point of care ultrasound; NT – needle thoracostomy; ST – simple thoracostomy; TT – tube thoracostomy; TOHCA – traumatic out of hospital circulatory arrest; HEMS – helicopter EMS

**Figure 2:** Potential iatrogenic injuries based on needle thoracostomy insertion angle and anatomic location

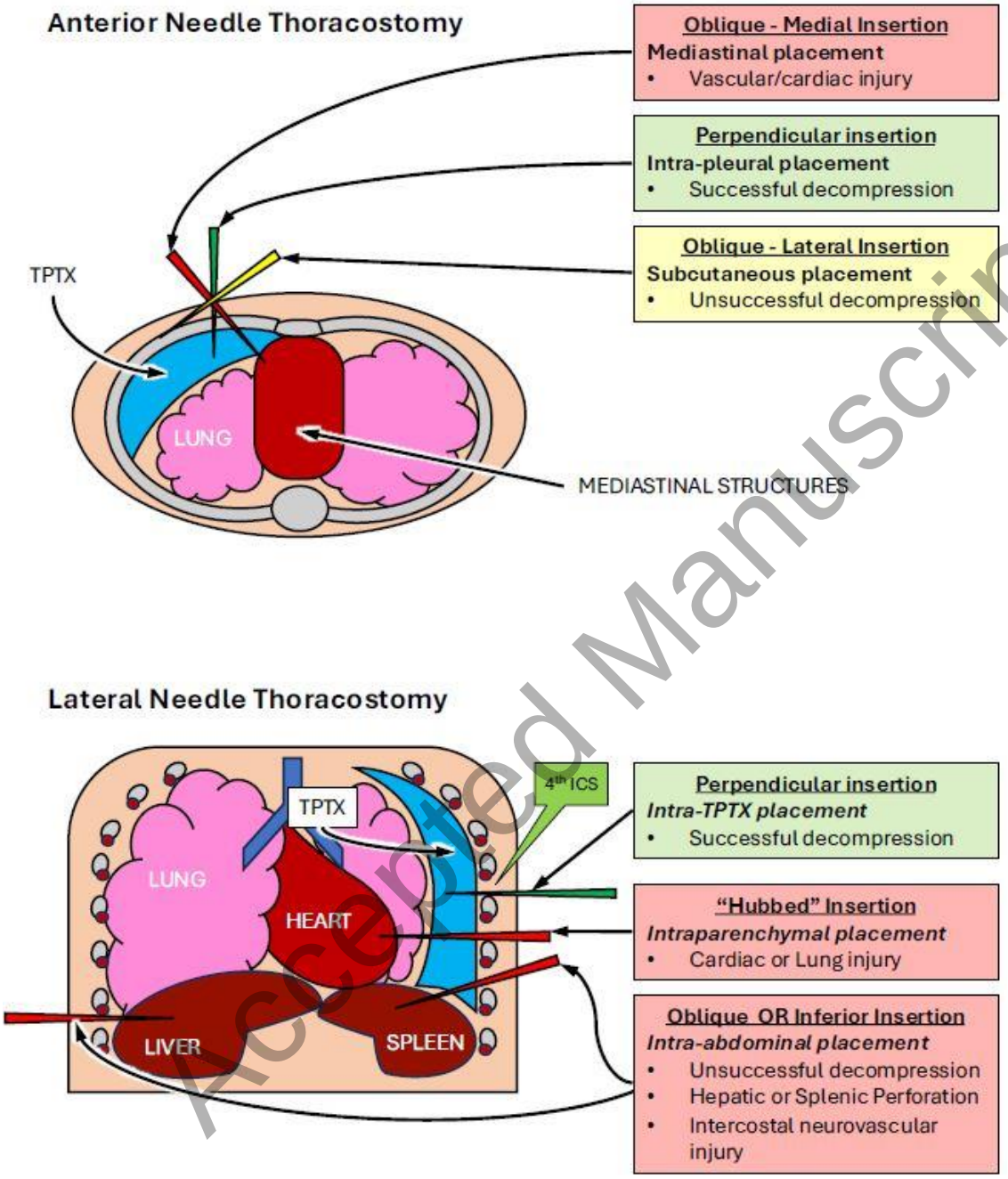




**Figure 2 footnotes:** TPTX – tension pneumothorax; 4ICSAAL – fourth intercostal space, anterior axillary line

**Figure 3:** Potential outcomes of needle thoracostomy device placement

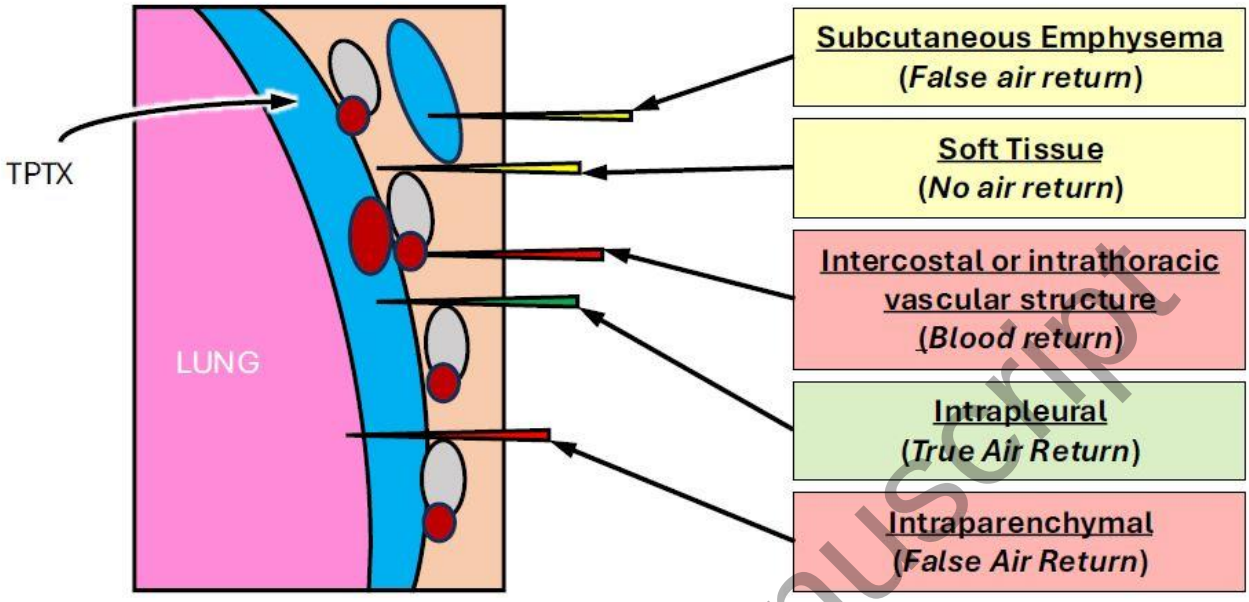


**Figure 3 footnotes:** TPTX – tension pneumothorax

**Figure 4:** Potential tension pneumothorax assessment and treatment algorithm

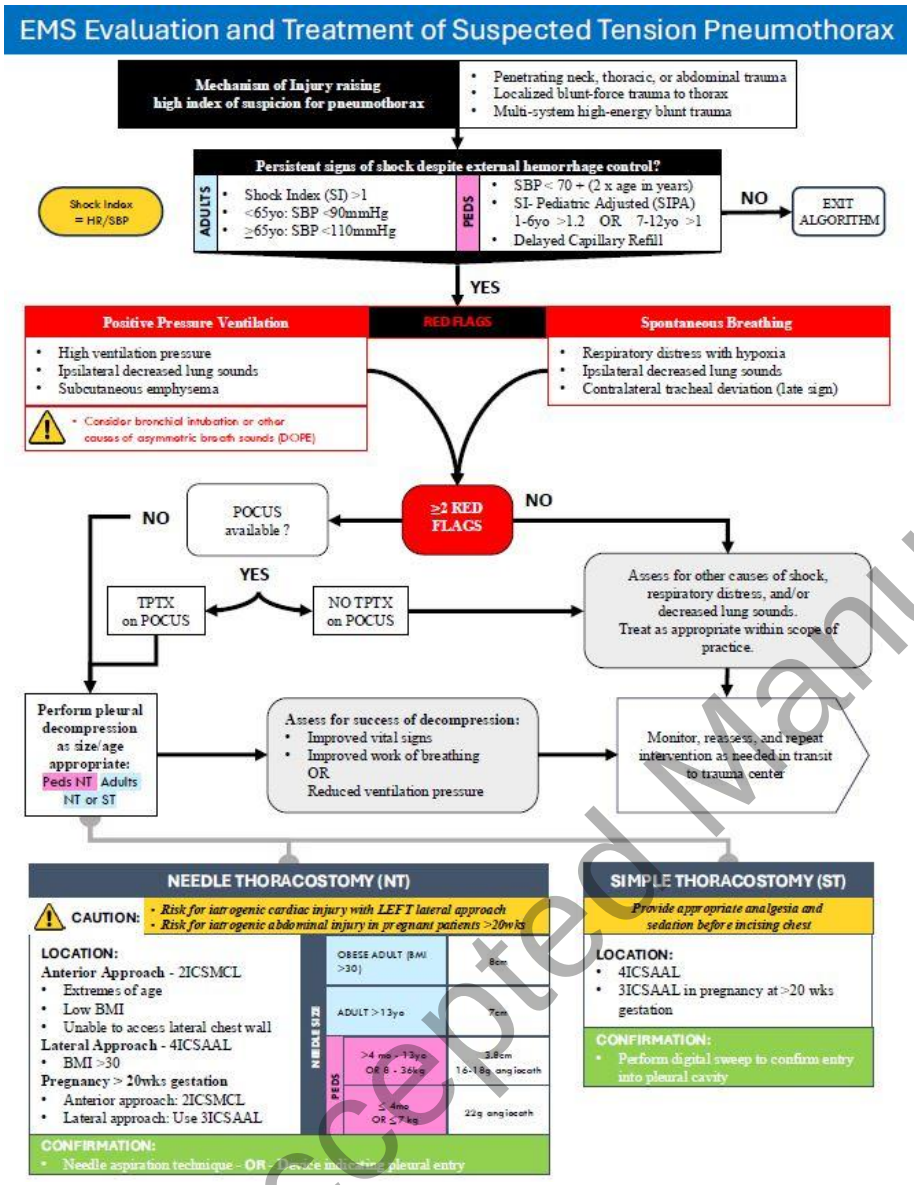




**Figure 4 footnotes:** 2ICSMCL – second intercostal space, midclavicular line; 3ICSAAL – third intercostal space, anterior axillary line; 4ICSAAL – forth intercostal space, anterior axillary line; BMI – body mass index; HR – heart rate; NT – needle thoracostomy; POCUS – point of care ultrasound; SBP – systolic blood pressure; SI – shock index; SIPA – shock index, pediatric adjusted; ST – simple thoracostomy; TPTX – tension pneumothorax; yo – years old

**Table 1:** Topic areas for literature content classification

| |
|---|
| Field identification of pneumothorax |
| Point of Care Ultrasound detection of pneumothorax |
| Needle Thoracostomy |
| Simple Thoracostomy |
| Tube Thoracostomy |
| Measures of successful pleural decompression |
| Chest seals and Open pneumothorax |
| Pleural decompression in traumatic out of hospital circulatory arrest (TOHCA) |
| Air Medical transport considerations for patients with pneumothorax |
| Education of EMS clinicians in pneumothorax evaluation and management |

TOCHA – Traumatic Out of Hospital Circulatory Arrest

**Table 2:** Literature search strategy for EMS management of traumatic pneumothorax

| **"EMS" Search Structure** | | |
|---|---|---|
| | **Search Terms** | **Search String** |
| **MESH Terms** | Emergency Medical Dispatch<br>Emergency Medical Services<br>Communication Systems<br>Emergency Medical<br>Technicians<br>Transportation of Patients | "Emergency Medical Dispatch"[Mesh] OR<br>"Emergency Medical Service Communication<br>Systems"[Mesh] OR<br>"Emergency Medical Technicians"[Mesh] OR<br>"Transportation of Patients"[Mesh] OR |
| **Text Search** | air medical<br>air medicine<br>aeromedical<br>aero-medical<br>aeromedicine<br>aero-medicine<br>ambulance*<br>emergency medical service*<br>emergency medical technician*<br>emergency services<br>ems<br>emt<br>field triage<br>first responder*<br>paramedic*<br>prehospital<br>pre-hospital | "air medical"[Title/Abstract] OR<br>"air medicine"[Title/Abstract] OR<br>"aeromedical"[Title/Abstract] OR<br>"aero-medical"[Title/Abstract] OR<br>"aeromedicine"[Title/Abstract] OR<br>"aero-medicine"[Title/Abstract] OR<br>"ambulance*"[Title/Abstract] OR<br>"emergency medical service*"[Title/Abstract] OR<br>"emergency medical technician*"[Title/Abstract] OR<br>"emergency services"[Title/Abstract] OR<br>"ems"[Title/Abstract] OR<br>"emt"[Title/Abstract] OR<br>"field triage"[Title/Abstract] OR<br>"first responder*"[Title/Abstract] OR<br>"paramedic*"[Title/Abstract] OR<br>"prehospital"[Title/Abstract] OR<br>"pre-hospital"[Title/Abstract] |
| **"Pneumothorax" Search Structure** | | |
| | **Search Terms** | **Search String** |
| **MESH Terms** | Pneumothorax | "Pneumothorax"[Mesh] OR |
| **Text Search** | pneumothora*<br>thoracostom*<br>needle decompression*<br>flail chest<br>chest tube | "pneumothora*"[Title/Abstract] OR<br>"thoracostom*"[Title/Abstract] OR<br>"needle decompression*"[Title/Abstract] OR<br>"flail chest"[Title/Abstract] OR<br>"chest tube"[Title/Abstract] |
| **Search Execution Parameters:** | | |
| 1. ["EMS" Search Structure]<br>2. ["Pneumothorax" Search Structure]<br>3. 1 AND 2<br>4. #3 AND english[la] (*Limit to English Language*)<br>5. #4 AND human[mh] (*Limit to Human Studies*) | | |

none

**Table 3:** Symptoms and signs of tension pneumothorax in positive pressure ventilation and spontaneously breathing patients.

| Symptom or Exam Findings | Positive Pressure Ventilation | Spontaneously Breathing |
|---|---|---|
| Chest pain | Not applicable | 50-100% |
| Dyspnea or Respiratory distress | <10% | 40-100% |
| Ipsilateral decreased air entry/breath sounds | 30-50%<br>*90% of advanced TPTX* | 50-75% |
| Subcutaneous emphysema | 20-30%<br>*100% advanced TPTX* | <10% |
| Hyperresonance | <10%<br>*85% of advanced TPTX* | 30-45% |
| Contralateral tracheal deviation | <10%<br>*late finding in 60% of advanced TPTX* | <25% |
| Jugular venous distention | <20% | <15% |
| Ipsilateral thoracic hyper-expansion | 33% | <15% |
| High ventilation pressure | 33% | Not applicable |
| Altered mentation | Not applicable | <10% |
| Cyanosis | 75% of advanced TPTX | <10% |
| Hypoxia | >90%<br>*Rapid onset and decline* | 25-50% |
| Tachypnea | Not applicable | >45% |
| Tachycardia | 30-45%<br>*95% of advanced TPTX* | 30-75% |
| Hypotension (MAP <60mmHg) | >45%<br>*80% of advanced TPTX* | <25% |
| *Sudden onset* | 30-100% | <15% |
| *Progressive onset* | <15% | 30-45% |
| Respiratory arrest | Not applicable | <15% |
| Cardiac arrest | 30-45% | <15% |

TPTX – tension pneumothorax; MAP – Mean Arterial Pressure

**Table 4:** London Helicopter EMS indications for prehospital thoracostomy

| | |
|---|---|
| Absolute indications | Traumatic Arrest |
| | Low cardiac output state of unknown cause |
| | Evidence of Tension Pneumothorax |
| | • Hypoxia |
| | • Hypotension |
| | • Absent breath sounds |
| | • Tracheal shift |
| Relative indications | Positive Pressure Ventilation + chest signs localized to hemithorax |
| | Reduced air entry |
| | Subcutaneous emphysema |
| | Unilateral wheeze |
| | Bony crepitations/rib fractures |
| | Hypoxia or Hypotension + chest signs localized to hemithorax |
| No indication | Simple pneumothorax |
| | Unilateral chest signs without PPV, hypoxia, or hypotension |

PPV – Positive Pressure Ventilation

**Table 5:** Summary of minimum device specifications and technique modifications to improve needle thoracostomy safety and success based on patient factors.

| **Minimum needle lengths (cm) based on chest wall thickness at anterior or lateral NT sites**[§] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anatomic approach** | **Infant** *<1yo* | **Pediatric** *1-13yo* | **Adults** >14yo; *M-Male, F-Female* | | | | | | | | |
| | | | BMI <18.5 | | BMI 18.5-24.9 | | BMI 25-29.9 | | BMI 30-39.9 | | BMI ≥40 | |
| | | | M | F | M | F | M | F | M | F | M | F |
| Anterior *2nd ICS MCL* | 3.8 | 3.8 | 2 | 2 | 3.5 | 3.5 | 5 | 5 | 6 | 6 | 7 | 7 |
| Lateral *4th ICS AAL* | | | 1 | 2 | 1.5 | 2.5 | 2.5 | 3 | 3 | 3.5 | 5 | 5 |
| **Insertion Technique** | | | | | | | | | | | | |
| • Insert NT devices perpendicular to the chest wall<br>• Insert NT devices as close to the superior edge of the rib as possible<br>• Insert NT devices only deep enough to decompress the TPTX. ***Do not "hub" NT devices.***<br>• Utilize needle aspiration technique to confirm successful entry into pneumothorax space | | | | | | | | | | | | |
| **Anatomic site selection** | | | | | | | | | | | | |
| • >65 years old - Anterior approach may be preferred due to thinner chest wall at 2nd ICS MCL<br>• Left sided TPTX – Anterior approach preferred, or consider using shorter devices for left lateral approach to reduce risk of iatrogenic cardiac injury<br>• Anterior approach – Position arms above the head to make anterior chest wall thinner<br>• Pregnant patients at >20 weeks gestation – shift lateral NT site superiorly to 3rd ICS AAL or use anterior approach<br>• BMI > 30 – Lateral approach may be preferred due to potentially thinner chest wall | | | | | | | | | | | | |
| [§] based on Hsu et al | | | | | | | | | | | | |

yo – years old; 2ICSMCL – second intercostal space, midclavicular line; 4ICSAAL – fourth intercostal space, anterior axillary line; NT – needle thoracostomy; TPTX – tension pneumothorax; BMI – body mass index