# Wisconsin EMS Scope of Practice Change Request Worksheet

**Use:**
- To provide information which supports any proposed change in the psychomotor skills, types of medical devices, or list of medications allowed under the State of Wisconsin EMS Scope of Practice.

**Objective:**
- A comprehensive and standard review of proposed Scope of Practice changes will help ensure the safe and effective delivery of out-of-hospital care.

**Please address the following statements as best possible (citing and attaching references when applicable):**
- Provide a specific and detailed description of the skill, type of device, or medication you are proposing.

  A finger thoracostomy is a medical procedure used to treat a tension pneumothorax, a life-threatening condition often seen in trauma patients. Here's a detailed description of the procedure:

    Preparation
    Ensure personal protective equipment is worn. The patient should be in a supine position if possible. The procedure area is typically the 4th or 5th intercostal space, at the anterior or mid-axillary line on the affected side of the chest.

    Site Identification
    Palpate to identify the correct intercostal space. The space is usually just above the nipple line in males, and in females, it is in line with the breast tissue but may need to be adjusted due to breast size.

    Local Anesthesia
    If the patient is conscious and time permits, local anesthesia may be administered to reduce discomfort.

    Skin Incision
    Make a 2-3 cm incision with a scalpel over the chosen intercostal space. The incision should be long enough to allow the insertion of a finger.

    Blunt Dissection
    Use a pair of curved hemostats to bluntly dissect through the subcutaneous tissue and muscle, down to the intercostal muscles. Spread the intercostal muscles and pleura carefully to enter the pleural cavity.

    Finger Sweep
    Insert a gloved finger into the incision to sweep circumferentially inside the chest cavity. This is done to ensure that there are no adhesions and to fully release any trapped air or blood.

    Decompression

Once the pleural space is entered, air should escape, indicating a successful decompression. If blood is present, it may also be drained at this time.

Monitoring and Transport
Continuously monitor the patient's vital signs and respiratory status. Reassess for signs of recurrent tension pneumothorax, particularly after changes in patient positioning or during transport.

- What intended clinical applications are you proposing for use (complaint, condition, ages, parameters)?

  Finger thoracostomy is primarily intended for the emergency management of tension pneumothorax, which is a life-threatening condition where air is trapped in the pleural space and causes increased intrathoracic pressure, leading to reduced venous return to the heart and decreased cardiac output. The clinical applications proposed for the use of finger thoracostomy in the prehospital setting generally include:

  Complaint/Condition: Suspected tension pneumothorax resulting from traumatic chest injury, indicated by signs such as severe respiratory distress, tracheal deviation, hypoxia, hyper-resonance on the affected side, and hemodynamic instability.

  Ages: Finger thoracostomy is applicable to both adult and pediatric patients; however, the anatomy and size considerations for pediatrics are different, and the procedure should be adjusted accordingly as determined by the organization’s medical director.

  Parameters for Use:
    - Evidence of a tension pneumothorax not relieved by needle decompression or in cases where needle decompression is contraindicated or unsuccessful.
    - Presence of penetrating chest trauma with rapid deterioration.
    - Cardiac arrest scenarios with suspected tension pneumothorax where other reversible causes are being managed.
    - In a prehospital setting where transport times to definitive surgical care are prolonged, making immediate chest decompression necessary.
    - As a part of advanced trauma life support protocols when other interventions are not available or have failed.

  Contraindications:
    - Absence of signs of tension pneumothorax
    - overlying infection at the site of incision
    - coagulopathy (if not life-threatening)
    - minimal respiratory compromise

- What EMS provider levels do you feel should have access through their scope of practice, and why?

  Allowing critical care paramedics in the state of Wisconsin to perform finger thoracostomy as part of their scope of practice in the prehospital setting could significantly enhance the level of emergency care provided to patients with life-threatening thoracic injuries. Here are the reasons why this procedure should be included in their capabilities:

Tension pneumothorax requires immediate treatment to prevent death. The ability to perform finger thoracostomy on scene or during transport can be lifesaving, especially in rural or remote areas where transfer times to hospital care are longer.

Currently, paramedics can only perform “chest tubes” in the interfacility transport setting. This limitation creates a gap in care for prehospital patients who may develop a tension pneumothorax or for those who have a re-accumulation of air after needle decompression during transport from a 911 response/scene response.

Critical care paramedics possess advanced clinical skills and are often already trained in similar invasive procedures. Extending their scope to include finger thoracostomy is a natural progression that utilizes their expertise where it's most needed.

Early and appropriate management of chest trauma, including decompression of a tension pneumothorax, has been shown to improve patient outcomes. By expanding the scope of practice, paramedics can provide more comprehensive care that aligns with trauma life support protocols in both 911 response and interfacility transport settings.

In many other states, finger thoracostomy is within the scope of practice for paramedics. Adopting this practice in Wisconsin would bring consistency and ensure that patients receive the same standard of care, irrespective of geographical location such as Life Link III’s experience in Minnesota.

Research has shown that prehospital finger thoracostomy can be safely and effectively performed by trained paramedics, suggesting that the extension of this practice is supported by evidence.

Existing educational and certification frameworks can be adapted to include the necessary training and competency assessments for finger thoracostomy, ensuring that paramedics are well-prepared to perform the procedure.

Emergency medical systems are constantly evolving. Allowing finger thoracostomy in the prehospital setting reflects the adaptation of the system to meet the current demands of trauma care.

- There is a legal and ethical responsibility to provide the highest standard of care possible. If paramedics are trained and capable, it would be a disservice not to utilize their skills to the fullest to save lives. List any examples of current usage in a patient care setting, both in and out of the hospital.

Finger thoracostomy is utilized in various patient care settings to manage tension pneumothorax, which can occur due to trauma or spontaneously. Here are examples of its usage both in and out of the hospital:

**In-Hospital Settings**

**Emergency Department**: Finger thoracostomy is performed in the ED as an immediate intervention for patients presenting with signs of a tension pneumothorax, especially when a chest tube insertion is not immediately available or in cases of traumatic cardiac arrest.

**Operating Room**: During surgical procedures, particularly after thoracic or abdominal trauma, surgeons may perform a finger thoracostomy before placing a definitive chest tube if a tension pneumothorax is suspected.

**Intensive Care Unit**: the ICU, finger thoracostomy may be used in critical care management, especially if a patient suddenly decompensates due to a suspected tension pneumothorax.

Prehospital and Transport Settings

**Helicopter Emergency Medical Services (HEMS):** HEMS teams may perform finger thoracostomies when transporting critically injured trauma patients who are at risk of tension pneumothorax or when needle decompression has failed.

**Urban and Rural EMS**: In settings with prolonged transport times to trauma centers, EMS providers might perform a finger thoracostomy on the scene or en route to provide immediate relief from tension pneumothorax.

**Military and Combat Settings**: Military medics and corpsmen may perform finger thoracostomy in field conditions when immediate decompression of the chest is required to manage combat-related chest injuries.

**Special Operations**: In special tactical operations, such as SWAT medical support, providers may need to perform a finger thoracostomy in the field if a tension pneumothorax occurs during an operation.

- Summarize the current evidence, concerning the proposed change, both for and against it, including benefits and improved effectiveness of patient care.

The study conducted by *High et al. (2016)* in the "Air Medical Journal" assesses the safety and efficacy of performing thoracostomy in pre-hospital settings, specifically by air medical crews. It examines the outcomes of patients who underwent finger thoracostomy (FT) or tube thoracostomy (TT) for tension pneumothorax, a potentially lethal condition often encountered outside of hospital environments. The retrospective analysis of 250 patients over 90 months revealed that **FT/TT can be utilized with limited complications, resulting in clinical improvement for a subset of patients. The procedure showed a low complication rate of 3.6%, with clinical improvements observed in 30% of patients**. This suggests that, with appropriate training and protocols, pre-hospital thoracostomy can be a viable intervention for managing pneumothoraces, potentially improving patient outcomes in critical settings.

The study by *Mohrsen et al*. published in the "Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine" presents a comprehensive review of complications associated with pre-hospital open thoracostomies. It highlights a **significant complication rate of 10.6%, primarily due to operator error or infection.** Despite these complications, the study suggests that, with careful patient selection and use of adjuncts like chest ultrasound, the **benefits of thoracostomy in managing tension pneumothorax in pre-hospital settings may outweigh the risks**.

The study by *Kaserer et al.* in the "American Journal of Emergency Medicine" evaluates the effectiveness of pre-hospital chest decompression techniques, emphasizing the high failure rate of needle thoracocentesis (NT) compared to tube thoracostomy (TT). **The retrospective analysis indicates that TT is more effective, achieving success in 83% of cases, while NT's effectiveness is notably lower.** The study suggests that TT should be considered in pre-hospital settings to ensure sufficient pleural decompression upon admission, highlighting the challenges of diagnosing and treating tension pneumothorax outside hospital environments.

The study by *Dickson et al.* in "The Journal of Emergency Medicine" assesses the effectiveness of simple thoracostomy (ST) performed by paramedics on patients with traumatic cardiac arrest and suspected tension pneumothorax. The retrospective case series, spanning from June 2013 to July 2017, involved 57 patients and demonstrated a significant presence of pneumothorax (32%), with a 7% survival rate to hospital discharge with normal neurological function. This indicates that **ST can be safely and effectively performed by well-trained paramedics in pre-hospital settings, potentially improving survival rates in traumatic cardiac arrest cases.** The study supports the high prevalence of tension pneumothorax in this patient population and suggests the need for further research to fully evaluate the benefits of ST in ground-based prehospital settings.

The systematic review by *Sharrock et al. (2021)* on prehospital paramedic pleural decompression techniques, including needle thoracostomy (NT) and finger thoracostomy (FT), suggests that while FT might be associated with lower complication rates, the higher mortality observed in FT cases could be indicative of more severe injuries or greater initial severity among these patients. This implies that **poorer outcomes may not necessarily reflect the intervention's effectiveness but rather the critical condition of patients undergoing FT.** Further research is needed to fully understand these dynamics and to ascertain the best practices for managing suspected tension pneumothorax in prehospital settings.

The body of evidence presents a nuanced perspective on the practice of paramedics performing finger thoracostomy in pre-hospital settings. While there are concerns regarding the complication rates and the need for careful patient selection and training, the potential for improving patient outcomes in cases of tension pneumothorax is evident. The evidence suggests that with appropriate training, protocol development, and careful implementation, pre-hospital finger thoracostomy can be a viable intervention for managing pneumothoraces outside the hospital, contributing to improved survival rates in critical cases.

- Do you know of any current barriers or hesitations for use (laws/regulations, risks, costs, training)? How can these be addressed to allow for safe practice?

Several barriers and hesitations can impact the use of finger thoracostomy in the prehospital setting, including by critical care paramedics. Addressing these concerns requires a multifaceted approach:

The scope of practice for paramedics is regulated at the state level. Any expansion to include finger thoracostomy would require legislative changes or updates to the regulations governing emergency medical services (EMS).

The Wisconsin Air Medical Council is bringing this forward to advocate for scope of practice changes based on evidence and the potential for improved patient outcomes.

There are concerns about the risks of the procedure, including infection, injury to internal organs, and incorrect performance, which can be barriers.

A comprehensive training program and establishing clear guidelines and protocols set forth by the program's medical director can minimize risks. Regular skills maintenance and simulation-based training can ensure proficiency. Adequate training needs to be available to ensure paramedics are competent in performing the procedure.

Programs that are supported by their medical directors would need to develop a standardized curriculum that includes didactic learning along with high-fidelity task trainers, cadaver lab, live tissue skills labs, and supervised clinical experiences.

By addressing these barriers through legislative advocacy, education, training, the safety and efficacy of finger thoracostomy as a prehospital intervention can be ensured, potentially leading to wider acceptance and incorporation into the scope of practice for paramedics.

- Describe the training you feel would be appropriate to properly implement this change.

Programs that are supported by their medical directors would needs to develop a standardized curriculum that includes didactic learning along with high-fidelity task trainers, cadaver lab, live tissue skills labs, and supervised clinical experiences.

A novel approach as described by Merelman, et al. (2022) describes The FINGER mnemonic as a teaching tool designed to aid in the learning and retention of the key procedural steps for performing a simple thoracostomy, commonly referred to as finger thoracostomy. It stands for:

F: Find Landmarks - Identifying the correct anatomical location for the procedure, typically the fourth or fifth intercostal space at the anterior to mid-axillary line.
I: Inject - Administering local anesthetic and/or pain medication to the area where the thoracostomy will be performed, ensuring patient comfort and reducing procedural pain.

N: No Infection Allowed - Emphasizing the importance of using a sterile technique to minimize the risk of infection. This includes wide cleansing of the skin with an antiseptic and the use of sterile gloves, and when possible, a cap, mask, and gown.

G: Generous Incision - Making a sufficient incision at the identified site to allow for effective decompression of the pleural space. A larger incision, recommended to be 3-4 cm, facilitates easier insertion and maneuvering of instruments or fingers.

E: Enter the Pleural Space - Carefully entering the pleural space above the rib to avoid damage to the neurovascular bundle that runs along the bottom of each rib.

R: Reach In - Inserting a finger into the pleural space to perform a sweep and ensure that the lung has been adequately decompressed and any potential adhesions broken up, reassessing the patient's condition thereafter.

This mnemonic encapsulates a concise and systematic approach to performing finger thoracostomy, aimed at enhancing the skill set of prehospital clinicians for the effective management of patients with tension pneumothorax or hemothorax.

- How do you plan to track usage and monitor patient care outcomes and patient safety events?

Life Link III currently tracks all advanced procedures through a comprehensive quality management program. We have an open reporting program internally to track adverse events as well as developed strong relationships with our receiving facilities to share outcome information for quality improvement purposes. We also have a survey that is left with the referring and receiving facility receiving provider as well as the patient/family.

- Please cite the references used to support your responses and attach as PDFs.

Dickson, R. L., Gleisberg, G., Aiken, M., Crocker, K., Patrick, C., Nichols, T., Mason, C., & Fioretti, J. (2018). Simple Thoracostomy for Traumatic Cardiac Arrest: Postimplementation Experience in a Ground-Based Suburban/Rural Emergency Medical Services Agency. *The Journal of Emergency Medicine.* https://doi.org/10.1016/j.jemermed.2018.05.027

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Kaserer, A., Stein, P., Simmen, H.-P., Spahn, D. R., & Neuhaus, V. (2016). Failure rate of prehospital chest decompression after severe thoracic trauma. *American Journal of Emergency Medicine.* http://dx.doi.org/10.1016/j.ajem.2016.11.057

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Name of person completing request for State of Wisconsin Scope of Practice change:

Kolby Kolbet 2/29/2024
Name Signature/Date

Medical Director attestation of involvement and support for requested State of Wisconsin Scope of Practice change:

Bjorn Peterson, MD 2/29/24
Name Signature/Date

*All requests for change in State of Wisconsin Scope of Practice will be addressed by the EMS Office via a thorough decision-making framework. Interested parties are welcome to attend open EMS Board and Committee meetings to hear discussion on the proposed change. Proposals will be handled in the order of greatest perceived importance to WI EMS.*

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Original Research

# Safety and Efficacy of Thoracostomy in the Air Medical Environment

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A B S T R A C T

*Objective:* The use of thoracostomy to treat tension pneumothorax is a core skill for prehospital providers. Tension pneumothoraces are potentially lethal and are often encountered in the prehospital environment.
*Methods:* The authors reviewed the prehospital electronic medical records of patients who had undergone finger thoracostomy (FT) or tube thoracostomy (TT) while under the care of air medical crewmembers. Demographic data were obtained along with survival and complications.
*Results:* During the 90-month data period, 250 patients (18 years of age or older) underwent FT/TT, with a total of 421 procedures performed. The mean age of patients was 44.8 years, with 78.4% being male and 21.6% being female; 98.4% of patients had traumatic injuries. Cardiopulmonary resuscitation was required in 65.2% of patients undergoing FT/TT; 34.8% did not require cardiopulmonary resuscitation. Thirty percent of patients exhibited clinical improvement such as increasing systolic blood pressure, oxygen saturation, improved lung compliance, or a release of blood or air under tension. Patients who experienced complications such as tube dislodgement or empyema made up 3.4% of the cohort.
*Conclusion:* The results of this study suggest that flight crews can use FT/TT in their practice on patients with actual or potential pneumothoraces with limited complications and generate clinical improvement in a subset of patients.



The use of thoracostomy to treat tension pneumothorax is a core skill for prehospital providers. Tension pneumothorax is uncommon but potentially lethal and is often encountered in less than ideal settings in the prehospital environment.[1] The use of needle thoracostomy (NT) has made its way into the skill sets of most, if not all, advanced life support prehospital providers and even into some intermediate and basic providers' skill sets.[1]

The use of either finger thoracostomy (FT) or tube thoracostomy (TT) has made its way into the practice of flight crews that are mainly composed of physicians, nurses, and paramedics. Tension pneumothorax occurs when air or blood is trapped in the pleural space, causing intrathoracic pressure to rise. This can be aggravated by patients being transported at altitude. Rising pressure can cause the collapse of internal thoracic structures including great vessels, the lungs, heart, and trachea. Patients can exhibit an obstructive-type shock picture coupled with profound dyspnea.[1]

The efficacy of FT/TT over NT has been brought up in the literature. The inability of the needle to actually penetrate the pleural space (eg, becoming kinked, dislodged, or clotted off) is a real possibility.[2,3] FT/TT allows the provider to penetrate the pleural cavity and definitively and quickly address air or blood under tension.

Performing FT/TT in the prehospital/air medical environment can be challenging; it is a complex skill and potentially lifesaving. The goal of this study was to describe the use of FT/TT in this environment and look at efficacy, survival, and complications.

## Methods

This was a retrospective chart review of air medical patient records from an electronic medical record system over a 90-month period. Waiver of consent was granted by an internal investigational review board.

### *Setting*

Vanderbilt LifeFlight is an air medical transport organization consisting of 5 rotor wing aircraft and 1 fixed wing aircraft covering

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a 50,000 square mile referral area within TN, KY, and AL. Medical crews consist of either a nurse/nurse team (both dual licensed registered nurse/emergency medical technician or registered nurse/emergency medical technician-paramedic) or a nurse/paramedic team. Roughly 2,300 to 2,500 patients are transported per year. LifeFlight began service in 1984 and is a Commission on Accreditation of Medical Transport Systems—accredited organization.

*Protocols*

Since the inception of LifeFlight, NT has been part of the flight crew's skill set. In 1996, TT was introduced into the skill set along with the option of performing FT for the patient in extremis. All patients who undergo thoracostomy have their charts reviewed by an internal quality assurance monitor and the medical director for appropriateness and protocol compliance.

The flight crew can perform TT under protocols set forth by the program's medical director. The skill of TT is taught during initial medical crew orientation using mannequins and in a fresh tissue cadaver laboratory. Skills teaching on animal models is also conducted during flight crew orientation. Maintenance and quality improvement oversight of the TT skill set are done via chart review and semiannual competency assessments.

The FT/TT protocol calls for the patient to exhibit 1 or more of the following: evidence of thoracic trauma such as ecchymosis, abrasions, crepitus, diminished/absent breath sounds, penetrating wounds, and/or presence of subcutaneous emphysema. The patient must also have an injury pattern that is consistent with the development of tension pneumothorax such as a penetrating injury or blunt trauma to the thorax. Other clinical findings in the protocol are vital sign or clinical findings indicating severe hypoxia and/or hypotension, especially in the setting of trauma arrest. The protocol calls for FT/TT to be performed on patients with multisystem injury or thoracoabdominal penetrating injury who are in trauma arrest (Table 1).

In general, TT is preferred over NT, especially when NT has been attempted with no improvement in the patient's condition. TT is performed using a #10 blade, Kelly clamp, and 36F chest tube in adults; graduated tube sizes are available for pediatric patients. A vertical incision is performed at the 4th to 5th intercostal space at the mid to anterior axillary line behind the pectoralis muscle. The tube is introduced to lay in the anterior position and sutured in. The tube is connected to a closed seal device. FT is performed the same way, but a tube is not introduced immediately into the pleural cavity. FT serves as a quick and definitive way to address or rule out tension pneumothorax. The same incision can be used later for a tube thoracostomy if the clinician so desires.

## Results

Data were extracted from a prehospital electronic medical record database. Inclusion criteria consisted of all patients being transported via LifeFlight who underwent TT or FT. Patients < 18 years of age who received either TT or FT from the flight crew were excluded.

A 90-month period was reviewed from July 2006 to December 2013. During this time, 13,347 adult patients were transported, and 250 patients received TT or FT (1.8%); a total of 421 FTs/TTs were performed.

Data extracted included basic demographic information, mechanism of injury or illness, and type of transport. Type of transport was classified as either a scene transport or interhospital transfer. A scene transport is any transport of a patient who has had a traumatic or medical event and has not been seen in a hospital but was picked up at a nonhospital locale. An interhospital transport is any patient transport that originates in a health care facility. The transport type consisted of 70% scene flights and 30% interhospital. The mean age for the cohort was 44.8 years and ranged from 18 to 89 years of age; men comprised 78% of the group. The cohort was overwhelmingly made up of trauma patients (98%) versus medical patients (2%). The trauma patient group consisted of either a blunt or penetrating-type mechanism; blunt trauma included motor vehicle crashes, falls, and so on and penetrating trauma gunshot and stab wounds. Table 2 summarizes the demographic data for the study group.

**Table 1**
LifeFlight Indications for Finger/Tube Thoracostomy

- Trauma arrest
- Shock with suspicious or unknown cause
- Shock or low cardiac output state with evidence of thoracic/abdominal trauma
- Shock or low cardiac output state with positive pressure ventilation

**Table 2**
Demographics of Patients Undergoing Finger/Tube Thoracostomy (N = 250)

| Characteristic | Number of Patients | % of Patients |
|---|---|---|
| Age | | |
| Age 18-65 | 222 | 88.8 |
| > 65 | 28 | 11.2 |
| Mean age | 44.8 | |
| Sex | | |
| Male | 196 | 78.4 |
| Female | 54 | 21.6 |
| Mechanism of injury/illness | | |
| Trauma | 246 | 98.4 |
| Medical | 4 | 1.6 |
| Trauma | | |
| Blunt | 195 | 78 |
| Penetrating | 51 | 20.4 |
| Gunshot wound | 42 | 16.8 |
| Stab wound | 9 | 3.6 |
| Type of transport | | |
| Interhospital | 73 | 29.2 |
| Scene | 177 | 70.8 |

Clinical data were also assembled. Patients were divided into 2 groups: individuals who underwent cardiopulmonary resuscitation (CPR) or were without vital signs were placed in 1 group. Patients who had measureable vital signs during the transport were placed in the other group. Survival beyond the initial resuscitation effort in the receiving emergency department was also tabulated; patients who left the resuscitation bay with measurable vital signs, typically to go for further workup or operative intervention, were classified as survivors. Patients who did not leave the resuscitation bay and were pronounced dead were classified as nonsurvivors. Other data points focused on the use of unilateral or bilateral FT/TT, clinical improvement, and complications (Fig. 1).

Within the study group, 163 patients required CPR (65.2%); of that group, 1 (0.58%) patient survived (an adult male with a single stab wound and pericardial tamponade). Of the patients undergoing CPR, 144 (88.3%) of them received either bilateral FT/TT with the goal of treating an actual or potential tension pneumothorax; 19 patients received unilateral FT/TT. All patients in this group were intubated before or during transport.

The remainder of the group (87 patients [34.8%]) did not require CPR. Survival for this group was much higher; 74 patients survived (85% and 29.6% of the total). Of the patients who survived, only 21 (28.3%) received bilateral FT/TT, whereas 53 (71.6%) patients received unilateral FT/TT. A subgroup of patients not requiring CPR did not survive and lost vital signs while in the resuscitation bay; 13 patients (15.0% and 5.2% of total) did not survive and were pronounced dead in the resuscitation bay. Of this group, 77% (67/87) were intubated before or during transport.

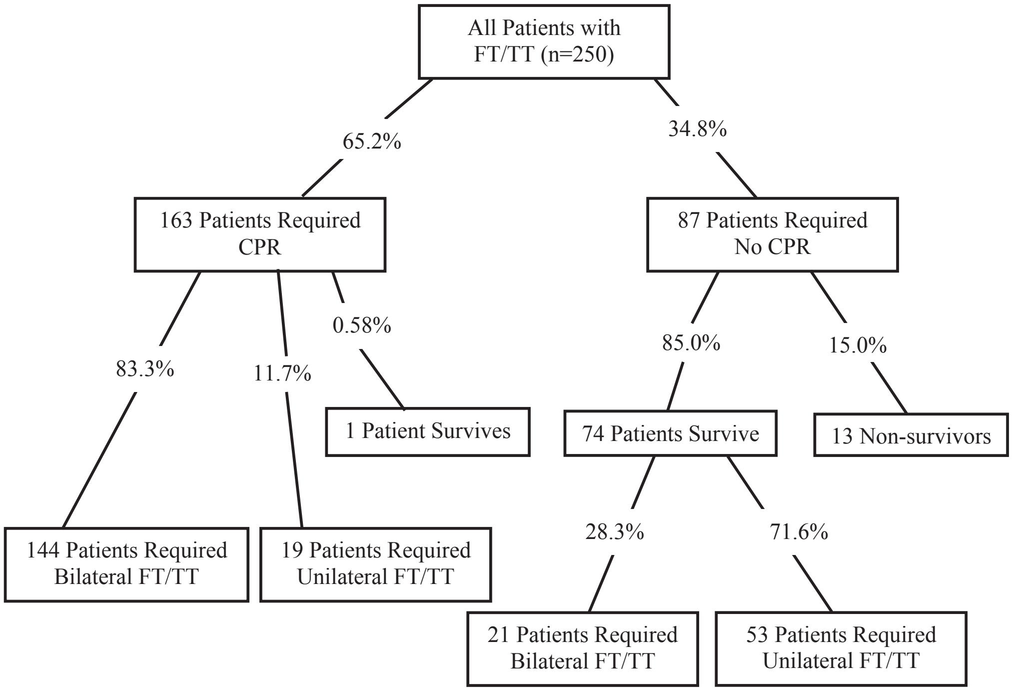


**Figure 1.** Patient grouping.

Other data abstracted included signs of clinical improvement (Table 3). Patients undergoing CPR or without vital signs were excluded from this portion of the data analysis. Criteria for clinical improvement focused on the reversal or improvement of tension pneumothorax pathology.

Of the study group, 75 (30%) exhibited clinical improvement. An increase in ventilator compliance was the most common clinical improvement; this was observed in 68% of patients (51 [68%]). The remainder of the patient group (32% [24]) exhibiting clinical improvement was described as having a rush of air or blood upon entering the pleural cavity. Of the patients who exhibited clinical improvement, 67 of them survived (89.0%). There were 8 patients (11.0%) who did not survive even though they exhibited clinical improvement after the procedure (Fig. 2).

Among the 250 patients receiving either TT or FT, 9 (3.6%) complications were reported. Complications were defined as either the tube being misplaced, the tube becoming dislodged during transport, damage to the underlying structures, or empyema formation. One patient (0.4%) had a reported empyema; the other patients (3.2%) all had tubes dislodged.

**Table 3**
Clinical Improvement Criteria

- Increase in systolic blood pressure of 5 mm Hg or more
- Heart rate improvement to > 60-100 beats/min
- Increase by 10 beats/min if < 60 beats/min
- Decrease by 10 beats/min if > 100 beats/min
- Oxygen saturation increase if < 95%
- Improvement in lung compliance of ventilated patients (tactile feedback via bag ventilation or decreasing peak airway pressure via ventilator)
- Rush or escape of air or blood upon entry into the pleural cavity

## Discussion

Controversy exists with regard to prehospital thoracostomy in general. Questions surrounding effectiveness, inappropriate patient selection, and potential complications are well-documented in the literature.[4]

A diagnosis of tension pneumothorax in the prehospital environment is difficult at best. Poor lighting, ambient noise, and limited access to the patient make assessment challenging. Prehospital providers must have a high index of suspicion for tension pneumothorax, especially in the polytrauma patient presenting in profound shock or trauma arrest. This cohort of patients presented either in arrest or extremis and met the criteria (Table 1) for FT/TT.

Questions regarding the effectiveness of prehospital thoracostomy have highlighted the problems with the use of NT in particular. Needle devices often fail to puncture the pleural cavity because of inadequate length, resulting in an unresolved pneumothorax.[5] The use of generic intravenous needles is common, but a few commercial devices of adequate length (> 4.5 cm) are available on the market. Complications after thoracostomy are troublesome, with some studies showing a complication rate as high as 20%; damage to internal structures and infection are 2 of the worst complications. Davis et al[8] described infection and dislodgement of the tube as complications from prehospital TT; the authors noted these 2 complications within the study cohort as well. Although NT by emergency medical service crews is common, both FT and TT tend to be more commonly used by crewmembers of air medical teams. Inappropriate patient selection has also been documented in the literature and remains a concern.[6]

This study describes the use of FT and/or TT in the prehospital setting by flight crews. There is limited literature on prehospital thoracostomy, especially thoracostomy performed by nurses and paramedics.[7,8] The data suggest that flight crews can use FT/TT in their practice on patients with an actual or potential pneumothorax with limited complications and generate clinical improvement in a subset of patients.

This study is not without limitations. Data collection was done retrospectively, and the clinical improvement criteria contain some subjectivity. A release of air was documented in many patients as an example of improvement; the prehospital setting can be challenging with regard to auditory feedback. The authors were concerned that using this as a criterion for clinical improvement may be too subjective. Some, if not all, patients had ongoing therapy,

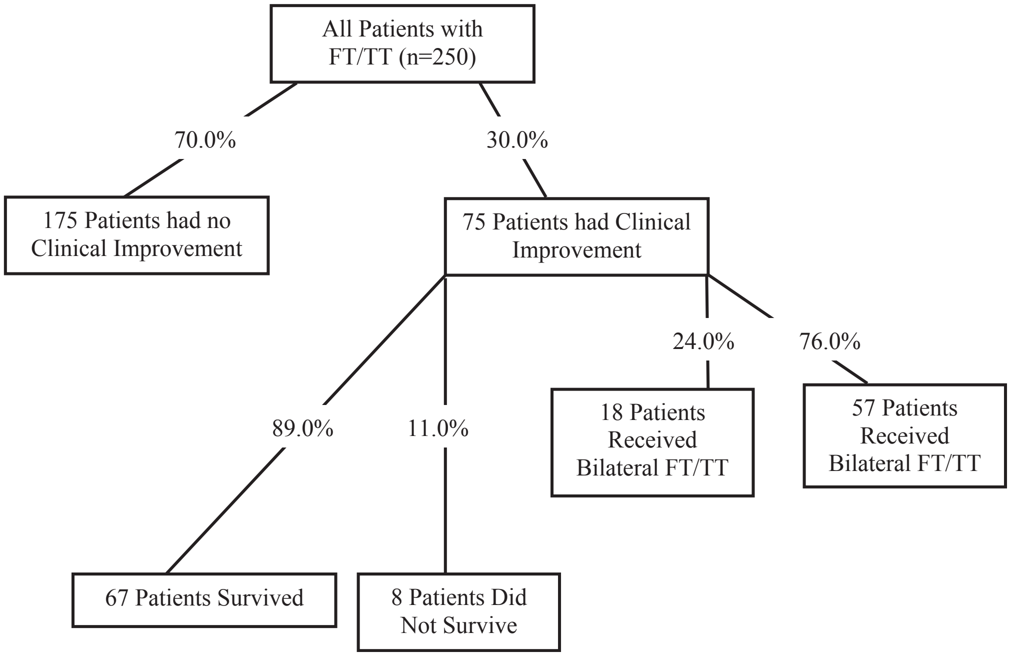


**Figure 2.** Patient grouping/clinical improvement.

namely volume replacement, which could have impacted clinical improvement along with FT/TT. It was not possible to have a positive diagnosis of pneumothorax within the study group mainly because of the austere environment, which is also a limitation of the study.

## Conclusion

Thoracostomy is a potentially lifesaving intervention that can be performed in the prehospital setting. Performing thoracostomy in this environment is not without complications and challenges. Opportunity exists for potential clinical improvement in some patients, but attention must be paid to provider training, identifying appropriate patients, securing the tube, and insertion technique. Emphasis should be placed on protocol development/treatment algorithm and medical supervision to ensure appropriateness.

Prehospital thoracostomy by air medical crews can be performed safely and effectively when coupled with high-quality training, clinical oversight, and robust quality assurance.

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REVIEW

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# Complications associated with pre-hospital open thoracostomies: a rapid review

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**Abstract**

**Background:** Open thoracostomies have become the standard of care in pre-hospital critical care in patients with chest injuries receiving positive pressure ventilation. The procedure has embedded itself as a rapid method to decompress air or fluid in the chest cavity since its original description in 1995, with a complication rate equal to or better than the out-of-hospital insertion of indwelling pleural catheters. A literature review was performed to explore potential negative implications of open thoracostomies and discuss its role in mechanically ventilated patients without clinical features of pneumothorax.

**Main findings:** A rapid review of key healthcare databases showed a significant rate of complications associated with pre-hospital open thoracostomies. Of 352 thoracostomies included in the final analysis, 10.6% (n = 38) led to complications of which most were related to operator error or infection (n = 26). Pneumothoraces were missed in 2.2% (n = 8) of all cases.

**Conclusion:** There is an appreciable complication rate associated with pre-hospital open thoracostomy. Based on a risk/benefit decision for individual patients, it may be appropriate to withhold intervention in the absence of clinical features, but consideration must be given to the environment where the patient will be monitored during care and transfer. Chest ultrasound can be an effective assessment adjunct to rule in pneumothorax, and may have a role in mitigating the rate of missed cases.

**Keywords:** Emergency medical services, Critical care, Thoracic injuries, Pneumothorax, Thoracostomy, Intraoperative complications

## Background

In addition to the oesophagus and lymphatic vessels, the thoracic cavity contains several life-sustaining structures including the heart and great vessels, airways, and lungs [1]. Injury to any of these can place a person at immediate threat of severe disability or death, making chest trauma a well-acquainted adversary of emergency pre-hospital care providers. Even though significant chest injuries are associated with adverse outcomes, they can manifest late and have proven difficult to identify on clinical examination [2, 3]. Leech et al. [4] list closed tension pneumothorax (T-PTX) as the most common severe pathology in major chest trauma (1 in 250), a condition where air is increasingly introduced to the pleural space without an ability to escape [1]. This can develop over a matter of minutes or several hours [5], and occurs when a conduit is created by a rupture of lung tissue or an open wound through the chest wall, or a combination of the two. Increasing volume of air in one side of the pleural cavity interferes with pleural adhesion and disrupts the negative-pressure mechanism normal ventilation relies upon. An ever-increasing pleural volume compresses the ipsilateral lung further inhibiting alveolar ventilation area, and rising pressure shifts structures such as the vena cavae contralaterally which reduces cardiac preload

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and eventually causes circulatory collapse. Significant haemorrhage into the pleural cavity can present a similar mass effect on the lung and mediastinal organs, but less often creates tension and introduces significant intravascular volume depletion as a co-pathology [4, 6].

Immediate mitigation of large T-PTX involves the release of air from the pleural cavity. In its simplest form this is done by inserting an open intravenous cannula through the chest wall and can be performed in the spontaneously breathing patient to alleviate high intrathoracic pressures. This is a safe intervention when applied in the correct circumstances [7] but has also been highlighted as often inadequate by Leigh-Smith & Harris [5] in 2004 and in several studies since [8, 9].

Traditionally, definitive treatment has been tube thoracostomies which involve performing a thoracic incision and placing an indwelling catheter attached to a one-way drainage system, to prevent air from re-entering the chest cavity [10]. More recently, Deakin et al. [11] described an open thoracostomy technique in the positive pressure-ventilated patient where altered ventilation physiology would allow an open conduit between the chest and environment without respiratory failure. Several authors have emphasised the success of this technique [12–14], which now is considered standard treatment for patients in traumatic cardiac arrest, or those who are positive pressure-ventilated with significant pneumo- or haemothorax with ventilatory compromise, where the skill is available [4, 15–17]. A recent systematic review by Sharrock et al. [18] sought to compare the safety and efficacy of needle- and open thoracostomies performed by non-physicians but was unable to establish one as definitively superior.

#### Additional file 1 contains an illustration of finger thoracostomies

Simple thoracostomy: (a) The 'triangle of safety' is identified by the centre of the axilla, the lateral aspect of musculus latissimus dorsi, and the lateral pectoralis major at the line of the nipple, with the arm fully abducted. (b) A bold incision is made through subcutaneous tissue in the fifth intercostal space at the anterior axillary line. (c) Muscle tissue is then dissected using a blunt instrument e.g., a set of arterial forceps, creating a canal to the parietal pleura which is then breached for access to the pleural cavity. A hiss of air, or ooze of blood or pus may present at this point, depending on underlying pathology. (d) The pleural cavity is explored using a finger, assessing for the position of the lung and any adhesions. The resulting canal is left open to allow air or fluid to escape and prevent compression of the lung. (Illustration by Megan Worsfold).

National guidance only describes the application of pre-hospital open thoracostomies in patients where there is a clinical suspicion of tension-pathology [4, 16]. However experience has shown this practice is implemented by some as a preventative measure, where a pneumothorax (PTX) may or may not be present, to avoid complications e.g., unrecognised T-PTX during transport. Decompression of significant PTX regardless of manifested tension has been promoted in secondary literature [19]. However, this concerns an interfacility setting with the ability to confirm the diagnosis with a chest x-ray, but the authors do not discuss what to do when there is an absence of clinical indicators. The Occult Pneumothoraces in Critical Care (OPTICC) trial [20] suggests it may be appropriate to observe patients receiving positive pressure ventilation (PPV) without overt signs of PTX, but this was an in-hospital study where close monitoring and immediate action was readily available. Pre-hospital critical care is typically delivered with a clinician-to-patient ratio of 2:1 with appropriate monitoring and the ability to decompress a developing tension as it presents. However environmental considerations such as vibration, dim lighting and noise are a few examples of potential barriers to identifying rapid changes in clinical condition [19] in the pre-hospital setting. A literature review was performed to explore potential negative implications of open thoracostomies and discuss its role in mechanically ventilated patients without clinical features of pneumothorax.

## Methods

### Selection criteria

A review across several databases was performed to assess the rate of complications in pre-hospital open thoracostomies. Only patients receiving positive pressure ventilation were included as normal respiratory physiology precludes the need for open thoracostomies in the spontaneously breathing patient [4, 16]. Only cases where at least one thoracostomy was performed pre-hospital was included, as this is the environment of practice the question relates to. The patient with chest injuries is emphasised, but papers discussing PTX from medical causes were also included if pre-hospital thoracostomy was a treatment strategy used.

Open thoracostomy is here defined as a surgical procedure where sharp dissection is used to break the skin of the chest in the 4-5th intercostal space in the anterior axillary line, following which blunt dissection and a finger-sweep creates a conduit between the pleura and the environment but without placing a chest tube. This can include cases where the procedure was performed without a clear clinical need, based on signs or symptoms of significant chest trauma to both sides of the chest or deranged physiology; or where only the side(s) of the chest that were injured were opened. Indwelling chest drains were excluded from the review if placed in the pre-hospital environment, as this procedure carries other risks of complication and would be rare in current pre-hospital practice [10, 21].

Outcomes measured were defined as:

- rate of iatrogenic injury to other structures; bleeding including iatrogenic haemothorax; loss of sensation; chronic neuralgia
- wound infection or empyema
- misplacement
- missed contralateral pathology requiring decompression
- delayed healing defined as time dependent on thoracic drainage, ventilation, or surgical wound care (Table 1).

## Search strategy

The PROSPERO and Cochrane Reviews databases were interrogated for any reviews answering the clinical question [22, 23]. No relevant articles were found in Cochrane CENTRAL database for clinical trials. Two related best evidence topics by Pritchard [12, 24] relating to patients with chest injuries and in traumatic cardiac arrest respectively were identified in the BestBETs database [25], but differs from this review as it excluded paediatric patients and included papers where indwelling tubes were inserted pre-hospital and were therefore excluded.

Searchable terms were developed from keywords discovered during scoping searches. Terms were connected using truncation and wildcards, and the "AND" or "OR" Boolean logic-operators: pre*hospital OR out-of-hospital AND; thoracostom*; AND iatrogeni* OR complication* OR infection OR empy?ema OR delay*. Subject headings or MeSH-terms were used across the Cochrane and Ovid interfaces, identified by using the interfaces' integral heading-browsers. Terms related to age and ventilation status were withheld from the search, and excluded at screening if not agreeing with selection criteria to ensure a sufficient sensitivity and search yield.

**Table 1** Selection criteria

| | |
|---|---|
| Inclusion | Pre-hospital setting<br>Positive pressure ventilated<br>Single or bilateral thoracostomies<br>Published 2000–2021 |
| Exclusion | Not English language<br>Pre-hospital chest drain<br>Traumatic cardiac arrest<br>Needle thoracostomy only<br>Case–control/qualitative designs |

Searches were performed across titles and abstracts in Scopus (Elsevier), CINAHL (HDAS), Medline (Ovid SP) and Embase (Ovid SP) on 6th March 2021 (Table 2). Papers were limited to those written in English and published between 2000 to 2021. Results were uploaded to Endnote X9 (3.3, Cite While You Write) referencing software and deduplicated, before manual screening of abstracts and full texts against selection criteria.

**Table 2** Search strategy

| | Terms | Scopus | CINAHL | Medline | Embase |
|---|---|---|---|---|---|
| 1 | Pre*hospital | 73 661 | 18 419 | 12 588 | 17 439 |
| 2 | Out-of-hospital | 52 710 | 6 787 | 12 624 | 18 749 |
| 3 | $ SH/MeSH | N/A | 13 537 | 47 783 | 48 802 |
| 4 | OR/1–3 | 109 233 | 23 647 | 61 641 | 78 986 |
| 5 | Thoracostom* | 6 926 | 773 | 2 325 | 3 262 |
| 6 | $ SH/MeSH | N/A | 1 181 | 2 997 | 1 243 |
| 7 | OR/5–6 | N/A | 1 712 | 3 018 | 3 790 |
| 8 | Iatrogeni* | 207 270 | 8 983 | 32 791 | 44 850 |
| 9 | Complication* | 3 097 082 | 675 868 | 947 927 | 1 390 713 |
| 10 | Adverse | 1 799 456 | 583 316 | 534 469 | 831 783 |
| 11 | Infection | 4 805 210 | 384 789 | 1 142 202 | 1 458 125 |
| 12 | Sepsis | 436 334 | 31 176 | 100 668 | 156 477 |
| 13 | Empy*ema | 30 485 | 1 605 | 9 686 | 11 618 |
| 14 | Bronchiectas* | 36 202 | 2 132 | 10 000 | 16 054 |
| 15 | Pain | 2 147 032 | 322 318 | 649 788 | 969 019 |
| 16 | $ SH/MeSH | N/A | 35 595 | 103 346 | 489 506 |
| 17 | OR/8–16 | N/A | 1 624 316 | 3 090 405 | 4 448 115 |
| 18 | Delay* | 2 801 825 | 106 906 | 493 565 | 670 336 |
| 19 | Prolong* | 1 427 447 | 56 571 | 389 541 | 524 377 |
| 20 | OR/18 + 19 | N/A | 159 064 | 856 233 | 1 155597 |
| 21 | Healing | 907 080 | 73 579 | 183 322 | 234 950 |
| 22 | Recovery | 3 017 527 | 106 412 | 463 874 | 614 261 |
| 23 | OR/21 + 22 | N/A | 164 306 | 640 509 | 839 667 |
| 24 | AND/20 + 23 | 517 883 | 11 516 | 55 984 | 79 312 |
| 25 | $ SH/MeSH | N/A | 54 375 | 92 138 | 439 343 |
| 26 | OR/24 + 25 | N/A | 65 458 | 147 171 | 515 468 |
| 27 | OR/17 + 26 | 10 240 619 | 1 656 484 | 3 180 724 | 4 756 714 |
| 28 | AND/4 + 7 + 27 | 31 | 31 | 47 | 49 |

$ SH/MeSH/Terms = Subject headings/MeSH

For Scopus: N/A

For CINAHL: (3) "Prehospital Care"; (6) "Thoracostomy +"; (16) "Postoperative Hemorrhage" OR "Postoperative Pain" OR "Surgical Wound Infection" OR "Iatrogenic Disease"; (25) "Treatment Duration" OR "Length of Stay"

For Medline: (3) Emergency Medical Services/; (6) Thoracostomy/; (16) Iatrogenic Disease/or Pain, Postoperative/or Postoperative Haemorrhage/or Surgical Wound Infection/; (25) Duration of Therapy/or Length of Stay/

For Embase: (3) Emergency care/; (6) Thoracostomy/; (16) Postoperative complication/OR Postoperative haemorrhage/or Postoperative infection/OR Postoperative inflammation/OR Postoperative pain/OR Surgical infection/OR Surgical injury/; (25) Treatment duration/OR "Length of stay"/

**Additional file 2 contains a PRISMA flowchart demonstrating the search and screen process**

### Data collection and analysis

Qualitative analysis of each paper was performed (Additional file 3: Table 1) and rated using the OCEBM Levels of Evidence [26] and GRADE criteria [27]. Data pertaining to complications were extracted, and common types of iatrogenesis or complications were clustered. Incidence of complications was calculated and is presented as counts and percentages of all complications and all thoracostomies. One paper was excluded from quantitative analysis as it did not follow patients beyond handover to the emergency department [13].

## Results

A total of five papers met the selection criteria after full text screening, all pertaining to procedures performed pre-hospital but only four describing outcomes beyond hospital admission [13, 14, 28–30]. The papers included a total of 350 patients receiving 427 thoracostomies (excluding traumatic cardiac arrest), of which 386 (90.4%) were in the pre-hospital environment and 41 (9.6%) were in hospital. Two-hundred-and-twenty-four patients (64%) were followed up past admission with a mortality rate of 28.5% (n = 64).

**Additional file 3 contains a landscape table of included studies with analysis**

### Indications and procedure

Open thoracostomies are universally indicated in the presence of a large PTX in patients receiving PPV, as this is associated with an increased risk of developing tension pathology [31, 32]. Massarutti et al. [14] defined a clinical diagnosis of simple PTX as decreased breath sounds, subcutaneous emphysema, serial rib fractures with chest wall instability, flail chest or penetrating chest wounds. Aylwin et al. [30] applied similar criteria but added the presence of a unilateral wheeze to the list of clinical signs and added a wider range of indications including undifferentiated hypotension, or unilateral signs of a PTX in the presence of hypoxia or hypotension. Aylwin et al. [30] used T-PTX as the indication for the procedure defined as hypoxia, hypotension, absent breath sounds and tracheal shift. Conversely, Massarutti et al. [14] defined T-PTX based on the result of the procedure, as determined by an apparent hiss of air and/or rapidly stabilising vital signs following the procedure. Chesters et al. [13], Hannon et al. [28] and Quinn et al. [29] did not elaborate on their clinical indications but included chest injuries presenting a high risk of PTX, or unexplained hypoxia or hypotension in all patients receiving PPV. All papers agreed on finger thoracostomies as appropriate routine measures in traumatic cardiac arrest, and described the procedure uniformly, most referring to the initial description of the technique by Deakin et al. [11] in 1995.

### Complications

Of the 352 procedures followed up past admission, 10.6% (n = 38) were associated with complications and of these 7.3% (n = 26) were caused by procedural error and subsequent injury, infection, or treatment failure, while missed or recurring PTX accounted for 3.4% (n = 12).

Of the 38 complications identified in this review (Table 3), iatrogenic injury including injury to underlying organs, unintended bleeding, induced haemothorax or unnecessarily created thoracostomies was most common (28.9%, n = 11). Failure to decompress underlying PTX despite attempt and misplaced incisions accounted for five (13.1%) and eight cases (21%) respectively, and missed PTX and recurrent tension accounted for eight (21%) and four (10.6%) cases, respectively. Only two cases (5.2%) of post-procedure infection were identified on follow-up, but of note, the use of prophylactic antibiotics is not discussed throughout the papers and can therefore not be assessed reliably. Excluded from these data is the study by Chesters et al. [13] which did not include any follow-up beyond the pre-hospital phase.

## Discussion

Pre-hospital open thoracostomies have shown to be effective at relieving T-PTX and retain patency, avoiding the time-consumption and complications associated with inserting a drainage tube [33]. Findings from this review support this with only 1.1% of PTX re-tensioning post-procedure, but there is an apparent paucity of studies assessing patient-focused outcomes from thoracostomies with only three of the five identified papers attempting follow-up beyond pre-hospital or emergency department care [14, 28, 30].

**Table 3** Complications

| Complication | No | % (*n* = 38) | % (*n* = 352) |
|---|---|---|---|
| Iatrogenic injury | 11 | 28.9 | 3.1 |
| Failed procedure | 5 | 13.1 | 1.4 |
| Misplacement | 8 | 21.0 | 2.3 |
| Infection | 2 | 5.2 | 0.5 |
| Recurrent PTX | 4 | 10.5 | 1.1 |
| Missed PTX | 8 | 21.0 | 2.2 |
| Total | 38 | 100 | 10.6 |

Careful balancing of benefit and harm, in line with the core principles of biomedical ethics [33] is required with any invasive procedure. Open thoracostomies are not benign with an overall procedural complication rate of 7.4% (excluding missed and recurrent PTX) and are associated with other complications such as long-term pain and cosmetic implications [10, 34], although these were not discussed in the papers in this review.

Finger thoracostomies in trauma are appropriate in circumstances where the patient has suffered chest injuries and is in cardiac arrest [15, 17]. It is also an established intervention in tension pneumothorax [15, 16], but the criteria for diagnosis are inconsistent between the papers in this review [13, 14, 28–30]. Unilateral chest pathology following trauma with features of reduced or absent air entry, with persistent or worsening hypoxia despite other measures, and/or features of shock or high ventilator airway pressures, should prompt consideration of a tension pathology requiring decompression [9, 16, 31]. However, there are many other potential causes for hypoxia, shock, and high airway pressures in the positive pressure ventilated trauma patient. Therefore, the decision to perform thoracostomy could be helped by using a checklist to ensure other less invasive causes are ruled out, before committing the patient to a surgical procedure [35].

Pre-hospital practice has evolved tremendously since Deakin et al. [11] first described the open thoracostomy method with the recent introduction of point-of-care ultrasound (POCUS) [36]. The technique is increasingly popular and advocated as an adjunctive decision-making tool in chest trauma [15]. POCUS has demonstrated high positive and negative predictive values, but due to significant inter-rater differences it is currently regarded too unreliable in completely ruling out pathology [37, 38]. Chest wall surgical emphysema in particular significantly reduces the utility of POCUS. That said, services that can ensure adequate training and competence should consider incorporating POCUS assessment into their guidelines. Further research on the utility of POCUS in pre-hospital chest injury management may help define those patient groups most likely to benefit from pre-hospital finger throactostomy.

## Limitations

This review has several limitations. All the included studies have used purposive sampling introducing potential selection bias, in this case patients requiring pre-hospital thoracostomies. This patient group typically suffers other major injuries associated with high morbidity and mortality and could confound outcomes, which cannot be adjusted for effectively with retrospective study designs and no comparison groups. Sample sizes are small and heterogenous; additionally, several of the papers demonstrated a high loss to follow-up with a mean of 71.4% (n = 64/224) of patients followed up to survival [14, 28–30]. This attrition bias could significantly affect the outcomes observed in the sample population hiding procedural complications as contributing to mortality in these patients. The retrospective nature of three of the studies [13, 28, 29] raises the possibility of reporting bias from inadequate or inaccurate notetaking. Conversely, prospective studies could encourage clinicians to create notes portraying more favourable outcomes than they otherwise would, knowing their practice is being assessed. Aylwin et al. [30] and Quinn et al. [29] included thoracostomies performed in the emergency department in their data which reduces the generalisability of these results to pre-hospital practice. The study by Hannon et al. [28] also included follow-up data on three cases who initially were in cardiac arrest which is not directly applicable to the selection criteria for this review.

## Conclusion

Pre-hospital thoracostomies are associated with a 10.6% complication rate based on the evidence identified in this review, most of which are due to operator error as opposed to unresolved or missed pathology. An open thoracostomy technique is likely to be as safe or safer than tube thoracostomies and remains the preferred option unless a tube is indicated for other reasons. Occult pneumothoraces can develop tension with subsequent shock or cardiac arrest, but it may be appropriate to withhold intervention in the absence of clinical features depending on the situation rather than 'empirical' thoracostomy. Clinicians should consider the environment where the patient will be monitored during care and transfer, and chest ultrasound can be used as an adjunct to assessment. Positive findings of pneumothorax on ultrasound may support a decision to decompress, but a normal ultrasound cannot exclude pathology and continuous patient monitoring remains pertinent. Existing evidence is too weak to establish definitive data on complications following pre-hospital thoracostomies, but this could be improved with prospective observational research with adequate follow-up beyond hospital admission.

### Abbreviations

POCUS: Point-of-care ultrasound; PPV: Positive pressure ventilation; PTX: Pneumothorax; T-PTX: Tension pneumothorax.

## Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13049-021-00976-1.

**Additional file 1. Figure 1**: Illustration of an open thoracostomy.

**Additional file 2. Figure 2**: PRISMA flowchart of the search and screen process.

**Additional file 3. Table 1**: Landscape table of included studies with summary of analysis.

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**Authors' contributions**
Methods, searching, review and manuscript by SMo. Manuscript review and revision by NM, SMc, and AC. All authors read and approved the final manuscript.

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All data generated or analysed during this study are included in this published article through (1) tables included in the paper, and (2) the published articles included in the review.

## Declarations

**Competing interests**
None of the authors have any relevant competing interests to disclose.

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# Failure rate of prehospital chest decompression after severe thoracic trauma

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ABSTRACT

*Introduction:* Chest decompression can be performed by different techniques, like needle thoracocentesis (NT), lateral thoracostomy (LT), or tube thoracostomy (TT).
The aim of this study was to report the incidence of prehospital chest decompression and to analyse the effectiveness of these techniques.
*Material and methods:* In this retrospective case series study, all medical records of adult trauma patients undergoing prehospital chest decompression and admitted to the resuscitation area of a level-1 trauma center between 2009 and 2015 were reviewed and analysed. Only descriptive statistics were applied.
*Results:* In a 6-year period 24 of 2261 (1.1%) trauma patients had prehospital chest decompression. Seventeen patients had NT, six patients TT, one patient NT as well as TT, and no patients had LT.
Prehospital successful release of a tension pneumothorax was reported by the paramedics in 83% (5/6) with TT, whereas NT was effective in 18% only (3/17). In five CT scans all thoracocentesis needles were either removed or extrapleural, one patient had a tension pneumothorax, and two patients had no pneumothorax. No NT or TT related complications were reported during hospitalization.
*Conclusion:* Prehospital NT or TT is infrequently attempted in trauma patients. Especially NT is associated with a high failure rate of more than 80%, potentially due to an inadequate ratio between chest wall thickness and catheter length as previously published as well as a possible different pathophysiological cause of respiratory distress. Therefore, TT may be considered already in the prehospital setting to retain sufficient pleural decompression upon admission.



## 1. Introduction

Chest decompression is an infrequent, life-saving procedure in trauma patients suffering from a tension pneumothorax. It occurs infrequently in trauma patients and interferes with cardiorespiratory function [1]. Therefore, rapid evaluation and urgent treatment by needle thoracocentesis (NT), lateral thoracostomy (LT), or tube thoracostomy (TT) is required in order to restore hemodynamic function and to improve respiration [1-3]. Needle thoracocentesis and TT were proved safe [4-6] and equally successful in the animal model [7]. Depending on the emergency medicine system, most commonly only designated emergency physicians are capable and allowed to perform TT, whereas NT may also be performed by skilled and educated paramedics.

Needle thoracocentesis is fast, simply applied, and used most commonly in the prehospital setting or during resuscitation [8]. The overall incidence of complications of NT is low [4,9]. According to leading trauma guidelines (Advanced Trauma Life Support®, Prehospital Trauma Life Support®) a needle or venous catheter should be inserted in the 2nd intercostal space (ICS) mid-clavicular line [2]. However, the reported success rate has a wide range varying from 5% to 96% [3,10-13]. One of the failure reasons is the insufficient length of standard needles and catheters for the 2nd ICS to reach the intrapleural space. Hence, some authors recommend the 5th ICS mid-axillar line for NT due to the smaller chest wall thickness in this area [14-18].

Tube thoracostomy ensures maximal pleural cavity evacuation and lung re-expansion [1,3]. The procedure entails a thoracostomy preferably in the 4th or 5th ICS mid-axillary line (Bulau) or the 2nd ICS midclavicular line (Monaldi), without any differences in the occurrence of misplacement or complications between both positions in trauma patients [19]. Complications related to TT, such as damage to the thoracic wall, the lungs, to abdominal or mediastinal organs, are less common since the use of trocars has been abandoned in favor of blunt dissection [1]. However, in the prehospital setting TT is blamed to increase resuscitation time and infection rate. While data on prolongation of the prehospital resuscitation time is incongruent [20,21], higher infection rate due to TT was not observed so far [5,21,22].

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Lateral thoracostomy is performed by blunt dissection and digital decompression through the pleura in the 4th ICS mid-axillar line and may be considered as an alternative in mechanical ventilated patients [23]. As decompression of the pleural space is the primary goal during resuscitation of the hemodynamically instable patient with suspected hemato- or pneumothorax, insertion of a chest tube is optional [3].

The aim of this study was to report the incidence of prehospital chest decompression, to analyse the effectiveness of the used techniques and to show the consecutive diagnostic thoracic findings and further treatment in the resuscitation area.

## 2. Material and methods

Data analysis was started after obtaining approval of the local ethics committee (Kantonale Ethikkommission Zurich, Switzerland, KEK-ZH-No: 2011-0382, PB_2016_01888).

### 2.1. Study design and participants

In this retrospective single-center case series study all adult trauma patients admitted to the resuscitation area of the University Hospital Zurich between 2009 and 2015 were included. Patients treated with attempted chest decompression in the prehospital setting underwent detailed analysis.

### 2.2. Setting

The University Hospital Zurich (USZ) is one of twelve level-1 trauma centers in Switzerland. In the Swiss emergency medicine system, most commonly a team of two registered paramedics, with a 3-year advanced federal diploma of higher education, treat a patient on the scene and transport the patient to the trauma center. In case of life threatening emergencies like severe trauma, a designated emergency physician, skilled and trained in advanced airway management, resuscitation and application of TT and NT is brought in parallel and in addition to the prehospital scene of action. Tube thoracostomy may only be performed by the designated emergency physician, whereas paramedics may perform NT. Later, in the resuscitation area of the hospital, a standardized clinical approach according to leading trauma concepts (Advanced Trauma Life Support®, European Trauma Course® and Definitive Surgical Trauma Care®) is provided. A chest X-ray and an ultrasound of the abdomen are taken in case of an acute problem in the primary survey. To diagnose and evaluate most relevant injuries, a primary whole-body-CT-scan is performed as soon as the patient is stable or stabilized. The trauma staff includes at least one senior and one junior anaesthetist, one senior and one junior trauma surgeon and anesthesia as well as scrub nurses.

### 2.3. Variables and data collection

All medical records of the included patients were reviewed. The ICD 10 GM (International Classification of Diseases, 10th-Revision, German Modification [24,25]) codes were used to identify (thoracic) injuries and the CHOP codes (catalogue of the Swiss Surgery Classification System [26]) for procedures. The data was encoded by professional medical coders.

Paramedic records of all patients undergoing prehospital chest decompression were reviewed. Number and location of prehospital chest interventions were extracted from these records. Prehospital chest decompressions were most commonly documented as NT and/or TT only, without information about catheter gauge and length. The treatment was defined as successful if any prehospital improvement in clinical (improved breath sounds or decreased dyspnoea if not intubated) and/or vital signs (improvement in systolic blood pressure, heart rate or oxygen saturation) was reported by paramedics or emergency physicians.

All chest X-rays and computed tomogram (CT) scans at admission were reviewed by the authors to analyse placement, location, and effect of the chest tubes or needles (catheters) and to identify the presence of rib fractures, lung contusions, hemato- or pneumothoraces.

### 2.4. Statistical analyses

Only descriptive statistic was applied to analyse data. Categorical data were reported in absolute numbers (n) and percent (%), numerical data as mean and standard deviation (±SD). All statistical analyses were performed by IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL, USA).

## 3. Results

### 3.1. Cohort

In a 6-year period, 24 of 2261 (1.1%) trauma patients admitted to the resuscitation area obtained prehospital chest decompression (Table 1).

The mean injury severity score was 37 ± 23. Pneumothorax was the leading traumatic finding, although it was not present in all patients undergoing prehospital chest decompression (Table 2). Other frequent injuries were rib fractures, flail chest, lung contusions and hematothoraces, while injuries of great vessels, of the bronchi or the diaphragm were less common. Two patients had only superficial thoracic injuries.

### 3.2. Prehospital needle thoracocentesis (NT)

Seventeen patients were treated with NT prior to arrival to the hospital (Fig. 1). All NT were performed at the 2nd ICS mid-clavicular line. Only three patients (18%) were - according to paramedic reports - successfully decompressed, although in all of these three patients, the needles were removed before admission or extrapleural in the primary CT scan (Fig. 2). Two of those patients received a TT in the resuscitation area to decompress a simple pneumothorax, while the third patient had no remaining pneumothorax and underwent no further treatment.

The majority (8 patients, 57%) of the unsuccessfully treated patients immediately received a TT in the resuscitation area at admission, before performing any X-ray or CT scan. An initial CT scan was performed in two patients, one requiring a TT directly afterwards due to a tension pneumothorax while the thoracocentesis needle was extrapleural. The other patient had no pneumothorax, although the needle was placed improperly, and needed no further TT after admission. In four patients, a chest X-ray was the first imaging method. Two of them had a tension hematothorax requiring an emergency department thoracotomy in the resuscitation area, one had a hematothorax requiring an urgent

**Table 1**
Overview.

| | | $n = 24$ |
|---|---|---|
| Age, mean (±SD), years | 43 | (±22) |
| Sex male | 19 | 79% |
| Body mass index, mean (±SD), ($n = 18$) | 25.2 | (±3.1) |
| Blunt trauma | 20 | 83% |
| Penetrating trauma | 4 | 17% |
| Prehospital endotracheal intubation | 20 | 83% |
| Prehospital cardiopulmonary resuscitation | 3 | 13% |
| Prehospital needle thoracocentesis (NT) | 17 | 71% |
| Prehospital chest tube thoracostomy (TT) | 6 | 25% |
| Prehospital needle & chest tube | 1 | 4% |
| ISS, mean (±SD) | 37 | (±23) |
| 1-day mortality | 6 | 25% |
| In-hospital mortality | 11 | 46% |
| Length of hospital stay, mean (±SD), days | 15 | (±14) |
| Late complications related to TT or NT | 0 | |

Data reported as frequency with percentage or mean (±SD).
ISS, Injury Severity Score.
SD, Standard Deviation.

**Table 2**
Thoracic injuries.

| | | $n = 24$ |
|---|---|---|
| Pneumothorax | 17 | 71% |
| Rib fractures | 15 | 63% |
| Flail chest or multiple rib fractures | 12 | 50% |
| Lung contusions | 12 | 50% |
| Hematothorax | 11 | 46% |
| Cardiac injuries (e.g. contusio cordis) | 5 | 21% |
| Thoracic great vessel injuries | 3 | 13% |
| Diaphragmatic injuries | 2 | 8% |
| Bronchus rupture | 1 | 4% |
| No intrathoracic injuries | 2 | 8% |

Data reported as frequency with percentage.

thoracotomy and the last received a chest tube due to progressive respiratory impairment, although no signs of a pneumothorax in the X-ray were observed.

### 3.3. Prehospital chest tube thoracostomy (TT)

Six patients were treated with TT (Fig. 1). All chest tubes were inserted at the 4th or 5th ICS mid-axillary line. Treatment was successful in five patients (83%), although in two of these five patients, the chest tubes were not placed properly - not all drainage fenestrations of the chest tubes were intrapleural (Fig. 3). They had to be replaced in the resuscitation area. Though transiently treated successfully, one patient received another chest tube in the resuscitation area and required an immediate sternotomy due to a cardiac gunshot wound with no previous X-ray or CT. In one patient, TT was not successful because of a completely dislodged chest tube; the remaining tension pneumothorax was decompressed by another TT after admission.

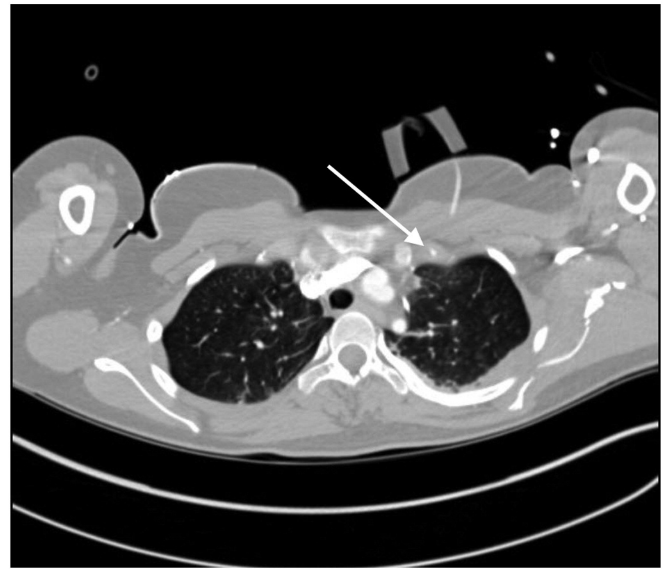

**Fig. 2.** (Example of an extrapleural needle) This figure shows a CT scan performed immediately after admission to the emergency department. NT was performed unsuccessfully on the left side at the 2nd ICS mid-clavicular line. The needle does not reach the pleural space. CT: computed tomography; NT: needle thoracocentesis; ICS: intercostal space;

### 3.4. Prehospital needle thoracocentesis and chest tube thoracostomy

One patient was treated first with NT and subsequently with TT in the prehospital setting (Fig. 1). Due to the proper placed chest tube

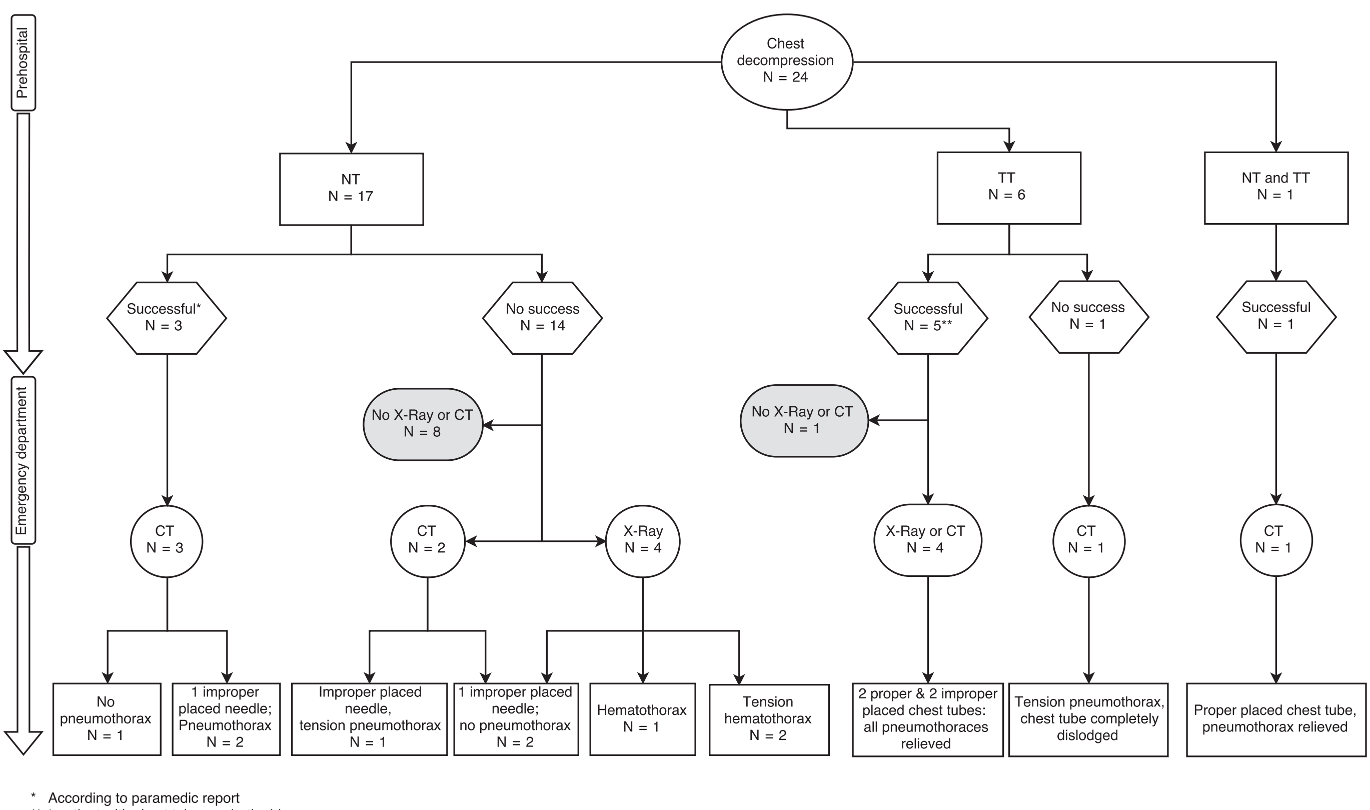


**Fig. 1.** Flowchart of all patients treated with needle thoracocentesis, tube thoracostomy or both in the prehospital setting. For patients undergoing prehospital chest decompression, success (judged by the paramedic team), first emergency department imaging, findings and diagnoses are presented. CT: computed tomography; NT: needle thoracocentesis; TT: chest tube thoracostomy;

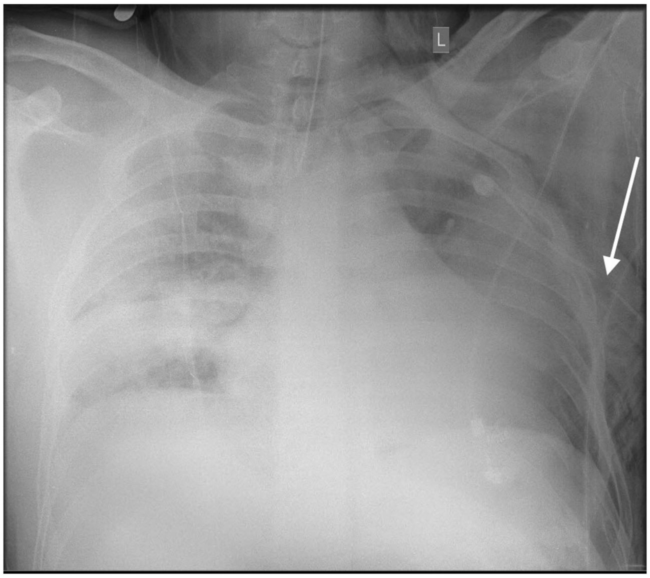


**Fig. 3.** (Example of an improper chest tube) This figure shows a chest X-ray as an example of a misplaced chest tube. Prehospital TT was performed on the left side at the 4th ICS mid-axillar line, but the chest tube was not inserted deeply enough. One of the tube fenestrations remains extrapleural (arrow).TT: tube thoracostomy; ICS: intercostal space;

and no signs of a persistent pneumothorax in the CT scan, no further action was mandatory.

## 4. Discussion

Chest decompression can be accomplished by NT, TT, or LT. Typical indication is the suspicion of a tension pneumothorax in the prehospital setting. The decompression success rate is reported to be low. The aim of this study was to report the incidence in an urban area and to analyse the success of these emergency procedures. This study showed that prehospital chest decompression in severely injured patients is rare (1.1%), however in the reported range between 0.68% and 30% [1,3,10, 27]. The reported success rate by clinical judgement of TT was over 80% in contrast to the success rate of NT being lower than 20%. However, half of all chest tubes were dislodged or not properly placed but accomplishing decompression in most cases. Chest wall thickness or catheter lengths, questionable suspected diagnoses, incorrect or dislodged needle/catheter placements, and possible side effects of NT remain a big concern.

NT is as effective as TT for relieving tension pneumothorax in an animal model [7]. However, the success rate of 18% by NT in our study was low, in accordance with the already published range varying from 5% to 96% [3,10-13]. This low success rate is not completely surprising. Many emergency medicine services in our vicinity are using standard venous catheters with a length of 33 mm to 50 mm for chest decompression. It was shown, that the average chest wall thickness on the 2nd ICS mid-clavicular line is 38 mm for men and 52 mm for women [28]. The chest wall in the 5th ICS anterior-axillary line was 13 mm thinner on average compared to the 2nd ICS mid-clavicular line [29]. A subcutaneous emphysema and multiple rib fractures may even increase chest wall thickness in trauma patients. Obesity increases chest wall thickness requiring at least a needle of 64 mm in length to be successful in 79% [30]. Also Zengerik et al. concluded that a greater needle length for certain population groups is necessary to improve the effectiveness of NT [31]. Inaba et al. performed a computed tomography-based analysis showing that NT decompression at the 2nd ICS mid-clavicular line would be expected to fail in 42.5% of cases compared to 16.7% at the 5th ICS in the anterior-axillar line if performed with standard venous catheters [29]. Several studies tackled this problem recently, investigating the use of longer catheters or a different location for NT. It was shown, that a catheter of at least 64 mm in length is needed to ensure that 95% of the patients would have a penetration of the pleural space for decompression [17]. If only standard venous catheters are available, NT of the 5th ICS anterior- or mid-axillar line may be considered to increase success, rate [28] although in this location the catheter might occlude more often during transport [32].

To diagnose a tension pneumothorax in the prehospital setting can be challenging. In our study three out of 17 patients (18%) treated with NT had no pneumothorax at all in the admission imaging. This indicates a questionable suspected diagnosis by paramedics and/or physicians on scene as well as an inadequate chest decompression maneuver. It was shown by Blaivas et al., that up to 26% of the patients treated with NT in the prehospital setting for a suspected tension pneumothorax, proved not to have had a pneumothorax originally [33], which was the case in three of our patients indicating another cause of the cardiorespiratory impairment.

Beside insufficient catheter length and questionable diagnosis on scene, hematothorax as the cause for respiratory distress may be another reason for an unsuccessful NT. All three patients in the study population suffering from a hematothorax underwent unsuccessful NT followed by urgent thoracotomy in the resuscitation area. These hematothoraces could be attributed to the thoracic injury mechanism and were not related to a NT complication.

Tube thoracostomy, or at least the lateral thoracostomy needed for tube insertion, in our study was safe and at least temporarily effective. Of the three misplaced chest tubes, only one failed due to primarily extrapleural placement. The remaining two misplaced chest tubes successfully relieved suspected tension pneumothorax, although not all drainage fenestrations were intrapleural (Fig. 3) on arrival to the hospital. No organ damage caused by the insertion of the chest tube could be detected in the CT scans at admission. Although some case reports from misplaced and/or fatal chest tube insertions are published [34-36], the complication rate is shown to be low [5,6,19,22], especially since the use of the trocar has been mostly abandoned in favor of blunt dissection [1]. Therefore, some authors consider TT as the treatment of choice for initial chest decompression [3]. Data on the prolongation of the prehospital resuscitation time due to TT is incongruent [20,21], but there is no evidence for an increased risk of infection [5,21,22]. To keep the time to hospital admission as low as possible, a simple thoracostomy without chest tube insertion was proved safe and effective and may be considered as an alternative to TT in mechanically ventilated patients [23], although this treatment was not observed in any of our patients.

Not all patients received a chest X-ray or CT scan immediately after admission. Those patients were generally in a critical condition suspected to require an urgent TT in order to improve cardiorespiratory function. Imaging was conducted as soon as the patients were stabilized, but those analyses did not allow to draw any conclusions about the initial placement of the needle or the presence of a pneumothorax. It may be that the NT did not improve the respiratory trouble or the NT transiently improved it, however it recurred.

### *4.1. Limitations*

Our study has several limitations. First, it is a retrospective analysis. The correct indication to proceed with NT or TT cannot be verified. Similar, once TT and NT is performed correctly in the prehospital phase of care, one cannot be truly certain that the diagnosis of tension pneumothorax was correct. Second, paramedic record did not always report the size of the needles or catheters used for NT, limiting our analysis on efficiency of different catheter lengths. Third, not all patients received a chest X-ray or CT scan directly after admission. Therefore, the initial placement of the needle or tube as well as the presence of a pneumothorax before further treatment in the resuscitation area remained unclear in some patients. The results may not be applicable to systems in which TT cannot be performed in the prehospital system and therefore the

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focus must be on appropriate catheter length for NT as well as proper performance of the technique.

## 5. Conclusion

Prehospital NT or TT is infrequently required in trauma patients. NT is associated with a high failure rate, potentially due to an inadequate ratio between chest wall thickness and catheter length as previously published. Therefore, TT may be considered already in the prehospital setting to retain sufficient pleural decompression upon admission. Different pathophysiological causes of cardiorespiratory distress (e.g. hematothorax) may also have made the paramedics to decompress the chest, without success. Better prehospital diagnostics may help to guide treatment.

*Abbreviations*

| | |
|---|---|
| CHOP | Swiss surgical procedures classification system |
| CT | Computed tomography |
| GCS | Glasgow coma scale |
| ICS | Intercostal space |
| ISS | Injury severity score |
| LT | Lateral thoracostomy |
| NT | Needle thoracocentesis |
| RA | Resuscitation area |
| SD | Standard deviation |
| TT | Tube thoracostomy |

## 6. Declarations

### *6.1. Ethics approval and consent to participate*

The local ethical committee of Zurich approved the study (KEK-ZH-No: 2011-0382, PB_2016_01888).

### *6.2. Competing interests*

Dr. Spahn's academic department is/has been receiving grant support from the Swiss National Science Foundation, Berne, Switzerland, the Ministry of Health (Gesundheitsdirektion) of the Canton of Zurich, Switzerland for Highly Specialized Medicine, the Swiss Society of Anesthesiology and Reanimation (SGAR), Berne, Switzerland, the Swiss Foundation for Anesthesia Research, Zurich, Switzerland, Bundesprogramm Chancengleichheit, Berne, Switzerland, CSL Behring, Berne, Switzerland, Vifor SA, Villars-sur-Glâne, Switzerland.

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In the past 5 years, Dr. Spahn has received honoraria or travel support for consulting or lecturing from: Abbott AG, Baar, Switzerland, AMGEN GmbH, Munich, Germany, AstraZeneca AG, Zug, Switzerland, Baxter AG, Volketswil, Switzerland, Baxter S.p.A., Roma, Italy, Bayer, Zürich, Switzerland and Berlin, Germany, B. Braun Melsungen AG, Melsungen, Germany, Boehringer Ingelheim (Schweiz) GmbH, Basel, Switzerland, Bristol-Myers-Squibb, Rueil-Malmaison Cedex, France and Baar, Switzerland, CSL Behring GmbH, Hattersheim am Main, Germany and Berne, Switzerland, Curacyte AG, Munich, Germany, Daiichi Sankyo (Schweiz) AG, Thalwil, Switzerland, Ethicon Biosurgery, Sommerville, New Jersey, USA, Fresenius SE, Bad Homburg v.d.H., Germany, Galenica AG, Bern, Switzerland (including Vifor SA, Villars-sur-Glâne, Switzerland), GlaxoSmithKline GmbH & Co. KG, Hamburg, Germany, Janssen-Cilag, Baar, Switzerland and Beerse, Belgium, LFB Biomédicaments, Courtaboeuf Cedex, France, Merck Sharp & Dohme AG, Luzern, Switzerland, Novo Nordisk A/S, Bagsvärd, Denmark, Octapharma AG, Lachen, Switzerland, Organon AG, Pfäffikon/SZ, Switzerland, PAION Deutschland GmbH, Aachen, Germany, Pharmacosmos A/S, Holbaek, Denmark, Photonics Healthcare B.V., Utrecht, Netherlands, ratiopharm Arzneimittel Vertriebs-GmbH, Vienna, Austria, Roche, Reinach, Switzerland, Sarstedt AG & Co., Nümbrecht, Germany, Schering-Plough International, Inc., Kenilworth, New Jersey, USA, Tem International GmbH, Munich, Germany, Verum Diagnostica GmbH, Munich, Germany, Vifor Pharma, Munich, Germany, Vienna, Austria and St. Gallen, Switzerland.

All other authors have no competing interests to declare.

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The study was not funded.

## Authors contributions

AK contributed to data collection, statistical analysis, data interpretation, drafting the manuscript and critical revision of the manuscript. PS contributed to data collection, data interpretation, drafting the manuscript and critical revision of the manuscript. AK/PS contributed equally to the manuscript. DS and HS contributed to data interpretation and critical revision of the manuscript. VN participated in the design and coordination of the study, contributed to statistical analysis, data collection and interpretation as well as drafting and critical revision of the manuscript. All authors read and approved the final manuscript.

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**Selected Topics: Prehospital Care**

# EMERGENCY MEDICAL SERVICES SIMPLE THORACOSTOMY FOR TRAUMATIC CARDIAC ARREST: POSTIMPLEMENTATION EXPERIENCE IN A GROUND-BASED SUBURBAN/RURAL EMERGENCY MEDICAL SERVICES AGENCY

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☐ **Abstract—Background: Tube thoracostomy has long been the standard of care for treatment of tension pneumothorax in the hospital setting yet is uncommon in prehospital care apart from helicopter emergency medical services. Objective: We aimed to evaluate the performance of simple thoracostomy (ST) for patients with traumatic cardiac arrest and suspected tension pneumothorax. Methods: We conducted a retrospective case series of consecutive patients with traumatic cardiac arrest where simple thoracostomy was used during the resuscitation effort. Data were abstracted from our Zoll emergency medical record (Zoll Medical Corp., Chelmsford, MA) for patients who received the procedure between June 1, 2013 and July 1, 2017. We collected general descriptive characteristics, procedural success, presence of air or blood, and outcomes for each patient. Results: During the study period we performed ST on 57 patients. The mean age was 41 years old (range 15–81 years old) and 83% were male. Indications included 40 of 57 (70%) blunt trauma and 17 of 57 (30%) penetrating trauma. The presenting rhythm was pulseless electrical activity 65%, asystole 26%, ventricular tachycardia/fibrillation 4%, and nonrecorded 5%. Eighteen of 57 (32%) had air return, 14 of 57 (25%) return of spontaneous circulation, with 6 of 57 (11%) surviving to 24 h and 4 of 57 (7%) discharged from the hospital neurologically intact. Of the survivors, all were blunt trauma mechanism with initial rhythms of pulseless electrical activity. There were no reported medic injuries. Conclusions: Our data show that properly trained paramedics in ground-based emergency medical services were able to safely and effectively perform ST in patients with traumatic cardiac arrest. We found a significant (32%) presence of pneumothorax in our sample, which supports previously reported high rates in this patient population.** 

☐ **Keywords—EMS; finger thoracostomy; needle decompression; simple thoracostomy; tension pneumothorax**

## INTRODUCTION

Trauma is a common encounter for the emergency medical services (EMS) provider and accounts for the number one cause of death in children and young adults (1). In a large series of trauma cases, chest injuries were thought to contribute to 20–25% of these traumatic deaths (2). Tension pneumothorax (TPT) is a well-described and common complication of blunt and penetrating chest injury, with a prevalence of 5–20% (3–6). Tube thoracostomy has long been the standard for treatment for TPT in the hospital setting yet is uncommon in prehospital care apart from helicopter EMS (HEMS). The majority of experience with prehospital chest tube decompression is from

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Europe or Australasia where there is a preponderance of HEMS physicians who have extensive experience in placing prehospital chest drains (6–9).

Simple thoracostomy (ST) has been used as an adjunct to tube thoracostomy for >2 decades. Deakin et al. first described the procedure for prehospital suspected pneumothorax in 1995 (10). In this series of patients, ST was an effective means for decompression in the prehospital setting. The procedure appeared effective, as demonstrated by little residual pneumothorax and good lung expansion on follow-up radiographs (10).

Our EMS is a suburban/rural non–fire-based 911 system with ∼65,000 calls for service annually in an 1100 square mile service area. We have 220 advanced life support medics supported by 900 emergency medicine technician basics from 13 fire departments in our county. In 2015, Escott et al. outlined a novel ST training system for ground-based EMS systems (11). Training consisted of an initial course of didactic instruction and procedural competency using an anesthetized swine model followed by annual skills check offs (11). Herein, we describe our postimplementation experience with ST.

## METHODS

We conducted a retrospective case series of consecutive patients with traumatic cardiac arrest where ST was used during the resuscitation effort. Data were abstracted from our Zoll emergency medical record (Zoll Medical Corp., Chelmsford, MA) using a standardized method for consecutive patients who received the procedure for a 49-month period between June 1, 2013 and July 1, 2017. We collected general descriptive characteristics, procedural success, presence of pneumothorax, return of spontaneous circulation (ROSC), survival, and neurologic outcomes on each patient. We conducted a 2-tailed Fisher exact test comparing patients with ROSC and ROSC with survival to discharge for patients who received ST along with historical control group of 50 patients with needle thoracostomy (NT). This study was approved by our institutional review board.

## RESULTS

During the study period we conducted ST on 57 patients. The mean patient age was 41 years (range 15–81 years) and 82% were male. The indications included 40 of 57 (70%) blunt trauma and 17 of 57 (30%) penetrating. The presenting rhythm was pulseless electrical activity 65%, asystole 26%, ventricular tachycardia/fibrillation 4%, and other/nonrecorded 5%. Forty-three of 57 (75%) procedures were bilateral. Eighteen of 57 patients (32%) had air return, 14 of 57 (25%) had ROSC, with 6 of 57 (11%) surviving to 24 h and 4 of 57 (7%) discharged from the hospital with normal mental status. Of the 4 survivors, all were blunt trauma mechanism with initial rhythms of pulseless electrical activity. In the 14 of 57 patients with ROSC, 11 of 14 (79%) had air return only, 3 of 14 (21%) had blood return only, and 2 of 14 (14%) had both blood and air return documented. Neither air or blood return was documented in 2 of 14 (14%) patients. We found no difference in transport times or rates of procedure performed on scene vs. en route. The average transport time for NT was 15.33 min vs. 17.04 min for ST. The rates of procedures performed on scene vs. during transport were similar for NT and ST (59% and 60%, respectively). There was not a statistically significant difference in those with ROSC (9/50 for NT and 14/57 for ST, respectively; $p = 0.4833$). We observed similar result for those discharged home after ROSC (0/50 for NT and 4/57 for ST; $p = 0.1212$). There were no reported medic injuries.

## DISCUSSION

Tension pneumothorax is a common life-threatening condition and cause of preventable mortality in both blunt and penetrating trauma (3–5). In the United States, prehospital management of suspected tension pneumothorax involves emergent needle decompression; if successful, this procedure demonstrates a substantial return of circulation rate with reported ROSC rates of 25% after the procedure (12). Needle decompression involves placing a standard 14-g, 4.5-cm angiocath into the pleural space using the second intercostal space midclavicular line or fifth intercostal midaxillary line landmarks. This technique may be suboptimal because of body habitus, needle placement, or mechanical factors that obstruct the free egress of air from the pleural space. There are numerous reports of needle decompression failures involving a combination of factors, including obstruction with blood or tissue, kinking of the catheter, and misplaced catheter (13–20).

In NT, size does matter. In a 2013 review of NT in obese patients, investigators found that a 4.6-cm catheter would reach the pleural space in 52.7% of the population, a 5.1-cm catheter would reach it in 64.8%, and a 6.4-cm catheter would reach it in 79% (21). Although the evidence would appear to support the longer is better theory, this must be balanced with the potential for inadvertent injury to underlying vascular structures. There are multiple reports of significant vascular injury with anterior placement in the second interspace midclavicular line approach (22,23). As for placement issues, there is conflicting evidence on whether the anterior second interspace midclavicular or fourth/fifth space anterior midaxillary is optimal. What is clear is that both approaches have significant failure rates and issues related to misplacement and iatrogenic injury (13–24). Given the problematic nature of needle decompression, tube thoracostomy has clear advantages but has reported complication rates ranging from 3–30% (25–29). Given the austere environments of prehospital medicine and the complication rate of tube thoracostomy, simple or finger thoracostomy may represent the most rational approach to thoracostomy in the prehospital setting.

ST uses the same initial surgical incision at the fourth intercostal space midaxillary line along with blunt finger dissection and clamp penetration to reach the pleural space. A repeat 360° finger sweep may be used to check for reaccumulation in the setting of any decompensation postprocedure (Figures 1–4) (10). In addition to ST, an alternative method was described by Beer et al. using the addition of a cuffed endotracheal tube (ETT) to ensure a patent pleural communication (30). Using the ETT method (ETT-augmented ST) described by Beer et al. in lieu of traditional thoracostomy tubes appears to have advantages in mean time of insertion and will allow for continual chest drainage to ensure no reaccumulation of air in the pleural cavity (Figure 5) (30). Our current guidelines allow for either ST or ETT-augmented ST in traumatic cardiac arrest with suspected thoracoabdominal trauma.

Our experience since initiation of this training and procedure has been uniformly positive with improved ROSC rates and neurologically intact survival rate 7% for ST vs. 0% for NT alone. Thoracostomy is not in the national core curriculum or scope of practice for paramedics. Texas has adopted delegated practice for EMS that allows for training and implementation of special procedures outside of the usual scope of practice for medics if there is medical director approval. Given the published failure rates of NT and prevalence of TPT physiology in the trauma population, it may be time to conduct larger safety and efficacy trials in nonphysician, ground-based EMS for ST/ETT -augmented ST. Our service has a robust clinical quality assurance and improvement process that reviews all cases of ST in our service. We have an open line of communication with the county forensic office that conducts postmortem examinations on all traumatic deaths in our county. To date, 3 complications have been reported in 57 patients. These include 2 extrapleural


**Figure 1. Thoracostomy kit.**

**Figure 2. Skin incision.**

**Figure 3. Clamp penetration of pleura.**

**Figure 4. Finger thoracostomy.**

placements with the tract never entering the pleural cavity and 1 case of right diaphragm and liver injury. This complication rate mirrors that of previous reports on the procedure. Given the narrow indication for traumatic arrest, we believe continuing the procedure is in the interests of our patients.

**Figure 5. Bougie-assisted tracheal tube thoracostomy.**

### *Limitations*

Our study was limited by its retrospective design and the small number of patients in each group. In addition, our population was predominately blunt trauma and a trend toward improved survival in these patients is likely related to the numbers of these patients rather than a benefit of the procedure in blunt trauma patients vs. penetrating mechanism.

## CONCLUSIONS

Our data show that properly trained paramedics in a ground EMS were able to safely and effectively perform ST in patients with traumatic cardiac arrest. We found a significant (32%) presence of tension pneumothorax in our sample, which supports previously reported high rates of tension in this population (5). In addition, we observed a 7% survival to hospital discharge with normal neurologic function. Further studies with larger samples of patients are needed to fully characterize the potential benefits of the procedure in a ground-based prehospital setting.

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## ARTICLE SUMMARY

**1. Why is this topic important?**

Little is known about the efficacy and safety of prehospital simple thoracostomy in patients with traumatic cardiac arrest.

**2. What does the study attempt to show?**

We attempt to show that paramedics can safety perform prehospital simple thoracostomy as well as its effect on survival rates.

**3. What are the key findings?**

Our study found no medic injuries, a 32% prevalence of tension pneumothorax, and an unusually high survival rate in blunt traumatic arrests in patients undergoing simple thoracostomy.

**4. How is patient care impacted?**

Implementing this procedure may improve survival rates in traumatic cardiac arrest.

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Feature Article

# FINGER: A Novel Approach to Teaching Simple Thoracostomy

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ABSTRACT

For decades, most prehospital clinicians have only been armed with needle thoracostomy to treat a tension pneumothorax, which has a significant failure rate. Following recent changes by the US military, more ground and air transport agencies are adopting simple thoracostomy, also commonly referred to as finger thoracostomy, as a successful alternative. However, surgical procedures performed by prehospital clinicians remain uncommon, intimidating, and challenging. Therefore, it is imperative to adopt a training strategy that is comprehensive, concise, and memorable to best reduce cognitive load on clinicians while in a high-acuity, low-frequency situation. We suggest the following mnemonic to aid in learning and retention of the key procedural steps: FINGER (Find landmarks; Inject lidocaine/pain medicine; No infection allowed; Generous incision; Enter pleural space; Reach in with finger, sweep, reassess). This teaching aid may help develop and maintain competence in the simple thoracostomy procedure, leading to successful treatment of both a tension pneumothorax and hemothorax.


Patients with thoracic trauma may present to prehospital clinicians with a tension pneumothorax, hemothorax, or hemopneumothorax, all of which may be rapidly fatal yet easily reversible. Needle thoracostomy (NT) has been the primary approach to treat a tension pneumothorax in prehospital care for decades but has a significant failure rate, often because of poor technique and inadequate needle length or diameter.[1-4] The alternatives to NT are simple thoracostomy (ST), also commonly referred to as finger thoracostomy, and tube thoracostomy (TT). Both techniques provide direct confirmation that the chest has been entered and can also address any hemothoraces. To perform TT, additional training is required, along with more specialized equipment, and it carries a higher risk of infection.[4-6] Although there are no studies directly comparing these techniques, clinical experience suggests that ST has a higher success rate than NT, with fewer steps than TT. For this reason, in the military setting, ST is recommended in refractory shock after at least two attempts at NT and after having addressed any hemorrhage when a tension pneumothorax or hemothorax is suspected and is within the provider's scope.[7] ST has been introduced in some civilian ground emergency medical services and critical care transport agencies and will likely become more common in the future despite not currently being included in the national scope of practice.[8] Learning a surgical procedure can be challenging for clinicians who typically do not perform them. However, given the burden of disease and the risk of treatment failure with NT, it is reasonable and prudent to train prehospital clinicians to perform ST.[9-15] We have been teaching this technique for many years in several settings and have developed the FINGER (Find landmarks; Inject lidocaine/pain medicine; No infection allowed; Generous incision; Enter pleural space; Reach in with finger, sweep, reassess) mnemonic to help providers learn and retain the key procedural steps. This process is derived from the TT procedure because it is essentially the same technique without tube placement.[16,17]

The views expressed in this article are those of the authors and do not reflect the official policy or position of the Medical College of Georgia, University of New Mexico School of Medicine, Department of the Army, Department of Defense, or the U.S. Government.

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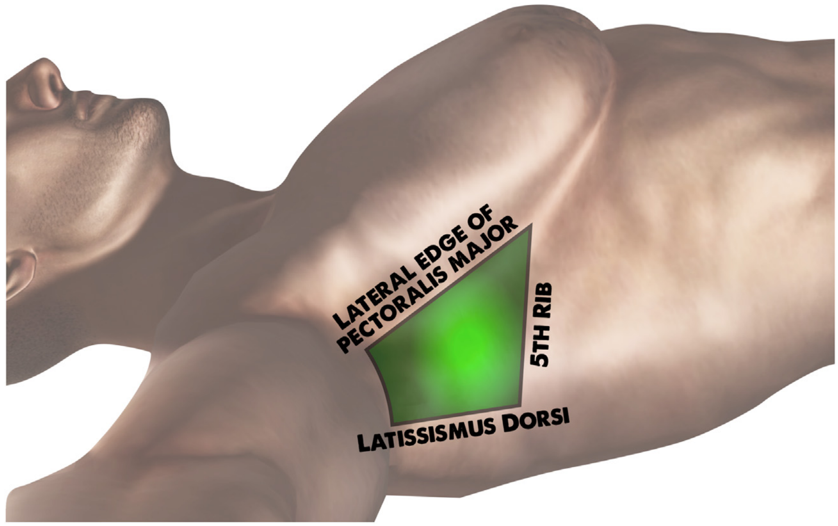


**Figure 1.** The site for finger thoracostomy.

## Description

*F: Find Landmarks*

The recommended site for ST is the fourth or fifth intercostal space between the anterior and midaxillary line, which is typically close to the nipple or inframammary fold. The incision is performed above the rib to avoid the neurovascular bundle running below each rib. The "triangle of safety" can be identified to approximate the correct site and help ensure the incision is above the diaphragm (Fig. 1). It is bordered by the pectoralis major anteriorly, the latissimus dorsi posteriorly, and the nipple line/fifth rib inferiorly. In patients with larger breasts, the nipple line may be a poor landmark, and the inframammary line should form the inferior border.[16-18]

*I: Inject*

This step involves injecting local anesthetic and/or parenteral pain and/or sedation medications. This should not be performed in cardiac arrest or periarrest patients in whom deterioration may occur with procedural delay. Local anesthesia should be delivered to the skin and soft tissues down to the pleura. Insert the needle down to the rib, and inject local anesthetic into the periosteum. Then, using the rib for tactile feedback, track the needle superiorly until you can enter the pleural space. Parenteral options include ketamine, midazolam, and fentanyl.[16,17]

*N: No Infection Allowed*

Attempt to use a sterile technique if possible. The skin should be cleansed widely with an antiseptic, such as chlorhexidine. Sterile or clean gloves should be used. When possible, the providers should don a cap, mask, and gown.[16,17]

*G: Generous Incision*

The incision should be made parallel to bone along the fourth or fifth rib at the site identified previously. A no. 10 blade is recommended; incise the skin using the belly of the blade. Although advanced trauma life support recommends a 2- to 3-cm incision, the authors recommend a 3- to 4-cm long incision through the skin and soft tissue to ensure adequate length for more novice clinicians.[16,17]

*E: Enter the Pleural Space*

The pleural space should be entered above the rib, avoiding the inferior aspect of the ribs because of the risk of damage to the neurovascular bundle. This is best accomplished using a blunt Kelly clamp or a hemostat. This can require a fair amount of force, especially in muscular and young patients. A pop, or giving way of pressure, should be noted. The clamps are then withdrawn, spreading them widely to create a sufficient defect in the pleura and intercostal muscles to allow drainage of air and fluid without sealing itself off. Do not advance the Kelly clamps into the chest and spread because this will be ineffective. If Kelly or similar clamps are not available, entrance into the pleura may be performed sharply with a scalpel.[16,17]

**Table 1**
The FINGER Mnemonic

| Step | Note |
|---|---|
| F: Find landmarks | 4th/5th ICS, anterior axillary line |
| I: Inject lidocaine or pain medication | If time permits (not in arrest or periarrest) |
| N: No infection allowed | Prep with an antiseptic |
| G: Generous incision | At least 4- to 5-cm through soft tissue |
| E: Enter pleural space | Blunt Kelly clamp above the rib looking for pop or sharp if scalpel |
| R: Reach in with finger, sweep, reassess | Ensure proper location and release |

*R: Reach In*

After the pleural space is entered, a clean gloved finger should be inserted and a sweep performed to ensure proper location. The lung, and possibly the diaphragm, should be palpated. Use caution because rib fractures may be present and can be sharp. To ensure adequate release of air or blood, vigorously sweep the finger up and down along the incision tract and side to side. Both air and blood may become trapped within the chest. Simply placing your finger or instrument in the chest does not guarantee a proper thoracostomy. Note any release of air or blood and reassess the patient's condition. Depending on environmental conditions and transport time, the wound can be left open to drain or a bandage placed. If bandaged, there is the possibility that the wound may need to be reopened if there is any sign of patient deterioration, possibly attributed to a recurrent tension pneumothorax or hemothorax[16,17] (Table 1).

## Complications

As with any invasive procedure, ST carries a risk of complications which providers and educators alike must be aware of. Infection is a common complication, especially in the setting of prehospital ST. We included “No infection allowed” because penetration of the thoracic cavity carries a risk of infection to the lung parenchyma (pneumonia), the pleural space (empyema), the ribs (osteomyelitis), and the soft tissue at the incision site (cellulitis). Care should be taken to always clean the skin and proceed with the greatest degree of sterility possible given the emergent nature of the procedure. When entering the pleural space, we specifically emphasize going above the rib to avoid the neurovascular bundle. Damage to the vascular structures under the rib could result in significant (and even life-threatening) bleeding as well as nerve injury. An injury to the intrathoracic structures is also a potential complication. It is important to stabilize surgical instruments and not to advance too deep into the thorax, allowing for only enough space to perform a finger sweep and the escape of air or blood. Overpenetration into the thorax could result in injury to the lung parenchyma, pulmonary vein or artery, great vessels of the chest, or even the heart. Likewise, correct identification of anatomic landmarks is important because damage to underlying structures outside the thorax is possible. In particular, performing the procedure inferior to the fourth or fifth intercostal space (below the triangle of safety) could lead to inadvertent penetration of the abdominal cavity and damage to structures, such as the spleen or liver. Finally, although not a direct mechanical complication of the procedure, providers should be aware that even if the procedure is performed properly, the lung may still not expand. A large air leak from the lung parenchyma, bronchopleural fistula, or direct injury to the bronchi may result in persistent drainage of air into the chest and failure of resolution of the pneumothorax.[16]

## Rationale

Educating clinicians to perform surgical procedures competently can be challenging, especially for relatively infrequently performed procedures executed during high-pressure situations. Time constraints, pressure, increased workload, and environmental stressors all contribute to detrimental effects on technical skills performance.[19-21] Stress in these situations also has marked effects on recall, working memory, and other cognitive functions, which may affect clinical interventions.[22-25] This normal deterioration needs to be considered when designing didactic education delivery and training modalities.

Traditionally, ST and TT are taught as longer multistep procedures that consume multiple textbook pages.[26,27] However, in stressful situations, simpler guidelines and tools can be better.[28,29] Using concise memory aids, such as short mnemonics, may assist in comprehension of the procedure, as well as ensuring it is completed successfully without distraction.[30] Specifically, the FINGER mnemonic takes advantage of cognitive scientist George Miller’s theory of information processing capacity by condensing the procedure to 6 discrete steps.[31] Condensing the procedure to a succinct, 6-step procedure is better aligned with the principles of cognitive psychology and education theory and may provide a superior teaching approach.

The use of a mnemonic is only one part of developing procedural competency. Education should begin with reinforcing clinical identification of a tension pneumothorax and/or hemothorax followed by an indicated and efficient surgical procedure. The procedure should then be demonstrated, live or using videos, in the same stepwise manner as per the FINGER mnemonic. Learners should then have the opportunity to practice these steps on a manikin or, for improved fidelity, on a cadaver.[32] Finally, simulations should be designed to reinforce the essential steps of the procedure under conditions as close to reality as possible. Evidence suggests that although there are many effective methods to teach procedures, the most effective is likely using simulation and competency-based assessments.[33] Repetition under the guidance of an experienced instructor is essential.

Emergency reflex action drills (ERADs) can also be used in response to specific situations.[34] ERADs are preplanned and practiced responses to specific, emergent situations. They are designed to be performed under instances of high stress and cognitive burden when clinician performance may not be optimal. Clinicians who witness a loss of perfusion in a patient with significant trauma should perform a number of procedures reflexively, including pleural decompression.[35] An ERAD could be developed to incorporate the essential interventions, including ST. This ERAD would reduce the cognitive load and improve the efficiency and efficacy of interventions.

NT is limited in its ability to treat life-threatening injuries. The failure rate is high and can only address a tension pneumothorax. NT cannot treat a hemothorax, whereas ST addresses both pathologies. There are limitations to this procedure. In the event of a massive hemothorax, being able to replace lost blood is critical. Eventually, a chest tube must be placed and attached either to suction or, at minimum, a Heimlich valve. Treating life-threatening injuries with ST may temporize and stabilize. The need for definitive surgical intervention cannot be emphasized enough. Furthermore, there are many thoracic injuries that are not amenable to any treatment outside of the operating room in the hands of a surgeon.

## Conclusion

ST is a potentially lifesaving procedure that is already used in prehospital care but will likely become more common in the near future. We present the FINGER mnemonic as a teaching and learning aid to help develop and maintain competence for this high-acuity yet low-frequency procedure. Additional research would help to determine the role of mnemonics and optimal strategies for teaching this procedure.

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