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Prehospital needle thoracostomy: What are the indications and is a post-trauma center arrival chest tube required?

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ABSTRACT

Objective: This study examined the indications for prehospital needle thoracostomy (pNT), the need for tube thoracostomy (TT) following pNT, and the outcomes of patients who underwent pNT.
Methods: This study is a retrospective chart review of patients who underwent pNT prior to trauma center arrival. Patients were identified from the trauma registry and a quality improvement (QI) database from 9/2014–9/2018.
Results: 59 patients underwent 63 pNTs during the time period. The indication for pNT was "hypotension" in only 5 patients (7.9%). A CT chest was obtained on 51 NT attempts with the catheter in place. In 48 (94.1%) NT attempts, the catheter was not in the pleural space. 44 (69.4%) TTs were placed on admission date.
Conclusion: In patients undergoing pNT, hypotension was rarely the indication. Additionally, CT identified the catheter within the pleural space in only 3 (5.8%) NT attempts. TT placement was performed in 79.3% of NT attempts.

Introduction

It is estimated that the incidence of tension pneumothorax (tPTX) of prehospital, major trauma, and ICU patients may occur in 1%–3% of prehospital, major trauma, and ICU patients.[1] The 2018 Advanced Trauma Life Support (ATLS) 10th edition guidelines define the signs and symptoms of tPTX to include: chest pain, respiratory distress, tachycardia, hypotension, tracheal deviation away from the side of the injury, unilateral absence of breath sounds, cyanosis, neck vein distention, and elevated hemithorax without respiratory movement.[2] These ATLS guidelines state that if tPTX is suspected, immediate decompression is essential and can be achieved by prehospital needle thoracostomy (pNT) placement at the second intercostal space in the midclavicular line of the affected hemithorax.[2]

In the prehospital setting, emergency medical providers are trained to identify a tPTX and can perform a needle thoracostomy (NT) in order to save their patient's life. The need for NT relies entirely on whether or not the patient has the appropriate clinical indications of tPTX for NT. Indications for NT placement include: hemodynamic instability and hypoxia, hypotension and decreased breath sounds,[3] or decreased breath sounds and tracheal deviation. Controversy exists surrounding the suspected misuse of the procedure in prehospital patients that present with mild clinical signs of a potential tPTX.[4] Some authors insist pNT is a safe treatment to use in suspected tPTX, and the associated benefits outweigh the risks.[5,6] Other authors have produced data that indicates few patients are benefitting significantly from pNT and that the procedure should be postponed until the patient arrives in the emergency department.[4] Furthermore, it has been reported that patients undergoing pNT in emergent situations may not actually have a tPTX, with a reported error rate of 26%.[7] These findings emphasize the importance of accurate assessment of tPTX before pNT as this procedure can lead to complications including causing a pneumothorax in and of itself.[3]

At some centers, the standard practice is to place a tube thoracostomy (TT) in all patients who have undergone needle decompression in the prehospital setting.[7,8] In 2017, Kaserer et al. found pNTs to have a failure rate as high as 80% potentially due to factors such as inadequate ratio between chest wall thickness and catheter length.[9] Due to this high failure rate and potential error in prehospital diagnosis, some centers choose to radiographically verify

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that PTX is present prior to placing a TT in stable patients. Although it has been found that supine AP chest radiographs can miss as many as 24% of pneumothoraces,[4,10] recent studies have shown that ultrasound has a higher sensitivity for PTX detection and are more readily available.[3] Stable patients post-pNT with negative supine CXR or lack of ultrasound evidence of a PTX may not need a TT.

While pNT can save a patient's life in the case of tPTX, it is not without risk. These risks can include complications such as: cardiac tamponade, life-threatening bleeding due to injury of pulmonary or subclavian vessel, nontherapeutic placement, and injury to nerves at the site of placement.[8] These complications can be life-threatening and highlight why NT is to be avoided in patients who do not have the appropriate indications or signs of a tPTX. This study aimed to describe prehospital personnel indications for needle thoracostomy, needle placement accuracy, and related complications from needle decompression.

Materials and methods

The study presents a case-series of patients arriving at a Level I trauma center between 9/2014 and 9/2018 who had underwent pNT. Patients were identified from a quality improvement (QI) database and pNT-related data were collected prospectively. As part of an internal QI project, a standard form was completed by on-call residents or faculty and included questions for prehospital providers. Additional data, including demographics, were obtained from trauma registry, hospital medical records, and prehospital patient care reports (PCR). Patients 'dead on arrival' as well as patients less than 18 years of age were excluded. Our primary outcomes of interest were the indications for needle thoracostomy, needle placement accuracy, and related complications from needle decompression. Our secondary outcome of interest was the need for tube thoracostomy following arrival to the trauma center.

Variables included in this study were age, sex, height, weight, body mass index (BMI), injury type (blunt or penetrating), injury severity score (ISS), maximum abbreviated injury scale (MAIS) severity by body region, initial emergency department (ED) vital signs, and intubation status. Prehospital NT-related variables included indication for placement, needle location upon CT imaging, complications, and prehospital vital signs before and after pNT placement. If vital signs immediately prior to and after pNT were not identified, the first and last set of vitals recorded by prehospital personnel were used. Each pNT attempt was recorded including 4 patients who had bilateral pNT. Additionally, variables regarding hospital care of the patient's chest injuries were recorded. These included: TT placement (yes/no), timing of TT placement (before/after chest x-ray/after CT), and if the TT was placed in the ED or OR on admission date versus on the ward or in the intensive care unit within 24–48 h after admission.

Data were summarized using means and standard deviations for continuous variables and frequencies and proportions for categorical variables. Paired t-tests were used to test for differences in vital signs before and after pNT. All analyses were performed using SAS 9.4 (SAS Institute Cary, NC). The study was reviewed and approved by the University of Oklahoma Health Sciences Center Institutional Review Board.

Results

Throughout this 4-year period we treated 20,848 trauma patients. Thirty-four patients were diagnosed with tension pneumothorax, resulting in an incidence of 0.1%. The true incidence is difficult to ascertain as it is possible that the diagnosis of tension pneumothorax was not recorded in the EMS or medical records for some patients. During this period there were a total of 68 pNTs performed in 64 patients during our analysis period; four patients had bilateral pNT placement. Five patients were excluded from analysis, of whom 2 were 'dead on arrival' and 3 were less than 18 years of age. Following exclusions there were 59 patients and 63 NTs for analysis. There were 50 (84.7%) males and 9 (15.3%) females (Table 1). The mean age was 44(SD ± 17.5) and the mean BMI was 30.7(10.3). Blunt trauma was the primary injury type accounting for 81.4% of the patients and 78.6% of the patients had an ISS ≥16. Rib fractures or flail chest was identified in 39 (66.1%) patients and 48 (87.3%) had at least one thorax injury of AIS severity 3 or higher. Eighteen patients were documented to be intubated prior to or on arrival to the hospital. Mean systolic blood pressure (SBP) and heart rate (HR) upon arrival in the ED were 130(SD ± 24.5) and 101(SD ± 24.4) respectively. Respiratory rate (RR) and oxygen saturation (SpO_2) were 21(SD ± 8.3) and 95% (SD ± 5.1) respectively. In the prehospital setting, at least 74.5% of patients who underwent pNT had corresponding vital signs documented prior to and after pNT (Table 2). There was no statistically significant difference between the pre- and post-pNT heart rate, systolic or diastolic blood pressure, or respiratory rate. There was a statistically significant difference in the oxygen saturation prior to and after pNT ($p = 0.0015$).

Reduced or absent breath sounds was the most frequent indication for pNT reported by pre-hospital personnel occurring in 42 (66.7%) patients (Table 3). Whereas, hypotension was the indication reported for just 5 (7.9%) patients. Of the 51 pNT attempts that underwent CT imaging, 48 (94.1%) pNT catheters were not within the pleural space. The majority of the needles found outside the pleural space were located in subcutaneous tissue (72.9%). The anatomical location of the pNTs were all found to be placed anteriorly in proximity of the second intercostal space at the midclavicular line. Noted complications included 1 patient who developed a pneumothorax upon pNT removal, 5 catheters were identified to be kinked, 1 patient developed a subcutaneous hematoma, and 1 patient had a vascular injury that required video-

Table 1
Demographic and clinical characteristics.

Variables	n = 59
Age, Mean (±SD)	44 (17.5)
Gender, n (%)	
Female	9 (15.3)
Male	50 (84.7)
BMI, Mean (±SD)	30.7 (10.3)
Injury type, n (%)	
Blunt	48 (81.4)
Penetrating	11 (18.6)
ISS, Mean (±SD)	24.9 (12.8)
ISS<16	12 (21.4)
ISS≥16	44 (78.6)
Chest Injury, n (%)	
Flail Chest	12 (20.3)
Fracture Rib	27 (45.8)
MAIS≥3 by Body Region, n (%)	
MAIS Overall	52 (92.9)
Chest/thorax	48 (87.3)
Abdomen	13 (23.2)
Extremity	10 (17.9)
Head/Face	17 (30.4)
Intubation, n (%)	18 (31.0)
Initial ED Vitals, Mean (±SD)	
HR	101 (24.4)
SBP	130 (24.5)
DBP	83 (21.9)
RR	21 (8.3)
SPO_2	95 (5.1)
Temperature	36 (1.2)
GCS	10 (5.4)

Table 2
Vitals of patients before and after pre-hospital needle Thoracostomy(n = 59).

Variables, Mean(±SD)	Before Needle Placement	After Needle Placement	Pairs Used in TTEST	Mean Difference (95% CI)	p-value[a]
HR	101 (25.8)	97 (24.4)	48	2.81(-1.96, 7.59)	0.2421
SBP	116 (30.5)	121 (28.1)	45	−4.04(-10.83, 2.74)	0.2362
DBP	73 (22.4)	73 (22.0)	45	0.36(-4.66, 5.37)	0.8870
RR	23 (9.2)	24 (14.3)	47	−0.26(-4.77, 4.26)	0.9099
SPO_2,	89 (10.7)	93 (8.3)	44	−4.11(-6.55, −1.68)	**0.0015**

[a] p-value for paired T-Test.

assisted thoracoscopy for hemothorax evacuation. The exact vessel injured was not identified but it was determined the mechanism of trauma did not account for the hemothorax. Lastly, we found that each of the more than fifteen EMS and HEMS companies in the state of Oklahoma used a different type and size of NT. The most common documented types and available needle lengths being Turkel ® (8.9 cm), Cook ® (8.7 cm), and Angiocath (8 cm).

A total of 50 (79.4%) TTs were ultimately placed; 44 were placed in the trauma bay or OR at time of admission. The most common indication for placement of TT was pneumothorax, noted for 19 (43.2%) of pNT attempts (Table 4). Thirteen TTs were placed prior to the initial chest x-ray and 2 (3.8%) TTs were placed later in the patient's hospitalization 24–48 h after admission.

Discussion

Evaluating the trauma patient in the prehospital setting poses several challenges for the prehospital provider including limited equipment, lack of imaging capabilities, external distractions, and the need to transport to definitive care.[3] Due to the potential complications, pNT should be limited to patients with clear clinical signs and symptoms suggestive of tPTX, rather than simply 'decreased breath sounds.'[4]

The results of our study showed this was not the case as the majority of pNT attempts were performed for 'reduced or absent breath sounds' in 42 (66.7%) pNT attempts and only 5 (7.9%) pNT attempts were performed for hypotension. 'Reduced or absent breath sounds' could reflect patients having a 'simple' pneumothorax versus confounding variables such as the patient splinting from pain, lung contusions, pleural effusion or hemothorax, or other causes of unequal breath sounds.[3] 'Hypoxia' was the indication for 9 (14.3%) NT attempts and an argument could be made that a pneumothorax was a contributing factor for the hypoxia.

For patients with pre- and post-pNT vitals available, the only statistically significant difference was in oxygen saturation. Prior to pNT, oxygen saturation averaged 89% and post-pNT was 93% (p = 0.0015); one could argue the clinical significance of this finding due to the scarcity of recorded information in EMS run sheets making it difficult to ascertain whether improvement in oxygen saturation was a result of needle placement, supplemental oxygen or intubation. The average systolic blood pressure (SBP) prior to pNT was 116 mmHg and after pNT was 121 mmHg. Not only was there no statistically significant difference, the median systolic blood pressure was well above what would be considered hypotensive or a physiologic sign of tPTX. These results highlight the importance of education in appropriate physiologic signs of tPTX as one would expect patients to be hypotensive and hypoxic, as well as have decreased breath sounds.

One of the more surprising findings in these patients was the identified location of the tip of the pNT catheter on computed tomography (CT). Of the 63 pNT attempts included in this study, 51 had a CT of the chest while the pNT catheter remained in place. Imaging revealed the tip of the pNT catheter was not in the pleural space in 48 (94.1%) of the attempts imaged. When not identified in the pleural space, the tip was largely found in the subcutaneous tissue (35, 72.9%) and 3 (6.3%) within the lung parenchyma. These findings can be attributed to inadequate execution or technique but

Table 3
Pre-hospital needle thoracostomy.

Pre-Hospital Needle Thoracostomies	n = 63
EMS Verbal indication for needle, n (%)	
Hypoxia	9 (14.3)
Hypotension	5 (7.9)
Reduced or Absent Breath sounds	42 (66.7)
Other	7 (11.1)
Imaging Performed, n (%)	
Yes	60 (95.2)
No	3 (4.8)
*__Number of NTs imaged with CT__	51 (81.0)
**__Was Needle Thoracostomy in Pleural Space on CT,__ n (%)	**n=51**
Yes	3 (5.8)
No	48 (94.1)
If Needle Thoracostomy NOT in Pleural Space on CT, n (%)	**n=48**
Subcutaneous	35 (72.9)
Out of skin	4 (8.3)
Lung Parenchyma	3 (6.3)
Other	6 (12.5)
Complications, n (%)	**n=63**
Kink In Tube	5 (7.9)
Pneumothorax	1 (1.6)
Vessel Injury	1 (1.6)
Subcutaneous Hematoma	1 (1.6)

*Including only needle thoracostomies with imaging.
**Including only needle thoracostomies with CT (n = 51).

Table 4
Hospital interventions.

Variable: Patients with any Imaging	n = 60
[a]**Pneumothorax on Imaging,** n (%)	46 (76.6)
Variable: Needle Thoracostomies Placed	**n=63**
Number of Chest Thoracostomy Tubes Placed, n (%)	46 (73.0)
Chest Tube Placed in ED or OR	44 (69.8)
Delayed Chest Tube	2 (3.8)
[c]**Indication Of Chest tube,** n (%)	**n=44**
Pneumothorax (PTX)	19 (43.2)
Hemothorax (HTX)	2 (4.5)
HTX/PTX	8 (18.2)
Hemodynamic Instability	4 (9.1)
Hypoxia	6 (13.6)
Other	5 (11.4)
[b]**First Chest Tube in placement in reference to imaging,** n (%)	**n=46**
Before Chest X-ray	13 (28.3)
After Chest X-ray	15 (32.6)
After CT Chest	16 (34.8)
Later in Hospitalization	2 (4.4)

[a] Including only patients with imaging (n = 60).
[b] Including only patients with Chest Thoracostomy tubes placed on admission date (n = 46).
[c] Including only patients with Chest tube in ED.

could also be related to improper equipment (pNT type or length). The mean BMI for these patients was 30.7, indicating many of these patients were obese. We did not find a correlation with BMI and accurate needle placement. On further review of the 3 patients with a NT in the pleural space, we found these patients had BMIs ranging from 25 to 35. Again showing no correlation between BMI and accurate placement. Although this finding likely contributed to the low number of intrapleural NT catheter tips, Stevens et al. found that standard 4.4 cm angiocatheters will likely fail to reach the pleural space in up to 50% of trauma patients.[11] Other studies have also looked at chest wall thickness and catheter length including a meta-analysis by Clemency et al. which found that a NT catheter should be at least 64 mm in length to achieve a 95% pleural space penetration rate.[12,13] Regional epidemiologic factors may play a role in the success of NT success as 30.4% of our state population has a BMI of 30 or greater and 66.3% of the population has a BMI of 25 or greater.[14] The Oklahoma State Department of Health has set EMS protocols regarding tPTX clinical signs and technique to be utilized by prehospital providers. These guidelines include the use of a 15 gauge pneumothorax catheter or 14 gauge angiocatheter that is at least 8.25 cm.[15] We found that EMS providers varied in the types of pNT used and the various sizes of these types that were available. We believe that compliance of EMS protocols for pNT regarding the signs and symptoms indicative of pNT placement and standardized needle sizes and types for patients of various BMIs could help mitigate the number of needles not reaching the pleural space and could circumvent these epidemiologic obstacles.

With regard to placing TT, our study is in line with several others that suggest TT placement is not mandated in all patients who undergo pNT.[3,4,7] Of the 63 pNT attempts, 44 (69.8%) required TT placement in the ED or the OR at the time of admission. The majority of the patients had imaging prior to TT placement with only 13 (26.0%) of the 63 pNT attempts requiring TT placement prior to any imaging. Avoiding emergent placement of TT allows for a more controlled environment, choice of TT, tube positioning, and maximizing sterile barrier technique. Of the remaining 18 patients, 2 required delayed TT placement 24–48 h after admission and reasons for placement included pneumothorax after pNT and hemothorax.

Regarding the complications, 1 patient underwent CT Chest which showed the NT catheter tip within the lung parenchyma but no PTX. After removal of pNT catheter, the patient developed a PTX requiring TT placement. Five catheters were found to be kinked either on exam or on imaging and one patient developed a subcutaneous hematoma. One patient was found to have a hemothorax on the side of pNT with the mechanism of injury unlikely to have caused it and likely represents a vascular injury from the pNT. Wernick et al. published a comprehensive clinical review of existing data and included the incidence of various complications. Iatrogenic pneumothorax was found to be occurring with an incidence of 1.8–11%, hemothorax occurring with an incidence of <1%, and vascular injury also having an incidence of <1%. This study also found that in >90% of patients undergoing pNT, there was a "lack of objective clinical improvement" which is in line with our findings.[8]

Our study had several limitations. First, it is a case series using data obtained from information sheets filled out upon hospital arrival as well as retrospective data. Second, some of the data sheets had missing information that could not be obtained from chart review and a small number of prehospital run-sheets were not available despite multiple attempts. Also, certain vital signs were not documented or the relationship of vitals to pNT were not documented. Vital signs prior to and after pNT were obtained in the majority of our study population. However, if a corresponding pre- and post-pNT vital sign was not documented both the pre- and post-NT vital sign were excluded from analysis. Third, prehospital personnel occasionally provided multiple indications for pNT, those patients were thus documented as 'other' or, if the primary indication was known, documented as such. If no indication was documented, it was recorded as 'other.' If primary indication was 'reduced or absent breath sounds' other clinical signs may have been present. Fourth, with regard to needle catheter tip location, it is possible some of the catheters were inadvertently pulled back from the pleural space and therefore documented as not in the pleural space. Also, it is difficult to determine the size needle used for each attempt, but all EMS companies should be following state protocols that recommend a 15-gauge pneumothorax catheter or a 14-gauge angiocatheter of at least 3.25 cm.[15] Lastly, not all patients had imaging obtained if they arrived in extremis or required emergent operative intervention. It should also be noted 13 TTs were placed prior to any imaging due to the patient being in extremis, having them placed at an outside hospital, or due to emergent operative intervention and thus these may skew our data.

Conclusion

This study demonstrated that pNT decompression is often done in patients with "soft signs" of tension pneumothorax as only 7.9% of patients had hypotension as the primary indication for pNT. Additionally, when performed, the catheter tip of the NT was rarely in the pleural space, occurring in less than 6% of our studied population. Of all pNT attempts, 69.8% required TT placement in the ER or in the OR at time of admission; however, only 26% of attempts required placement prior to any imaging. Immediate TT placement should not be mandatory in stable patients who have undergone pNT. For patients that may require TT placement, pre-procedure imaging allows for a controlled environment, adequate preparation, appropriate tube size selection, and possible avoidance of unnecessary TT. This study also highlighted the importance of prehospital personnel education on the diagnosis of tPTX and the technique of needle decompression which shows areas for potential collaboration. As a result of this study, our institution is currently working with EMS providers to provide education to increase the use of physiologic data as opposed to solely clinical findings in assessment of tPTX. We are also encouraging these providers to follow standardized Oklahoma State Department of Health protocols for clinical signs of tPTX, appropriate technique, and recommended needle types and sizes.

Conflict of interest disclosure

None of the authors listed on the submission titled "Prehospital Needle Thoracostomy: What are the indications and is a post-trauma center arrival chest tube required?" have any conflicts of interest to disclose.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2019.09.020.

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