Complications of needle thoracostomy: A comprehensive clinical review

Brian Wernick1, Heidi H Hon1, Ronnie N Mubang1, Anthony Cipriano1, Ronson Hughes1, Demicha D Rankin2, David C Evans3, William R Burfeind Jr1, Brian A Hoey1, James Cipolla1, Sagar C Galwankar4, Thomas J Papadimos2, Stanislaw P Stawicki1,5, Michael S Firstenberg6

Departments of Surgery and Research and Innovation, St Luke’s University Health Network, Bethlehem, Pennsylvania, Departments of Anesthesiology and Surgery, The Ohio State University College of Medicine, Columbus, Ohio, Department of Emergency Medicine, University of Florida, Jacksonville, Florida, Cardiothoracic Surgery, Summa Health System and Northeastern Ohio Universities College of Medicine, Akron, Ohio, United States

Address for correspondence: Prof. Stanislaw P. Stawicki, Department of Research and Innovation, St. Luke’s University Health Network, NW2-Administration, 801 Ostrum Street, Bethlehem, Pennsylvania 18015 USA. E-mail: stanislaw.stawicki@sluhn.org

ABSTRACT
Needle thoracostomy (NT) is a valuable adjunct in the management of tension pneumothorax (tPTX), a life-threatening condition encountered mainly in trauma and critical care environments. Most commonly, needle thoracostomies are used in the prehospital setting and during acute trauma resuscitation to temporize the affected individuals prior to the placement of definitive tube thoracostomy (TT). Because it is both an invasive and emergent maneuver, NT can be associated with a number of potential complications, some of which may be life-threatening. Due to relatively common use of this procedure, it is important that healthcare providers are familiar, and ready to deal with, potential complications of NT.

Key Words: Complications, emergent chest decompression, needle thoracostomy, tension pneumothorax

INTRODUCTION
Tension pneumothorax (tPTX) occurs in approximately one in 20 major trauma patients, although estimates of its incidence vary widely from <1 to 30%. Published data regarding the safety and complication rates of needle thoracostomy (NT) decompression for the treatment of tPTX are very limited. Given the very nature and inherent severity of tPTX, there are no randomized controlled trials looking at NT use, and the best available information consists of case reports, clinical series, and expert opinion. Relatively more is known about complications of tube thoracostomy (TT) for the management of pneumothorax (PTX), some of which may be translatable to NT management. The paucity of evidence regarding the morbidity associated with NT stems from the differences between the two procedures in the degree of urgency, methodology, technique, and important anatomic considerations. Although the traditional dictum is that most patients receiving NT have tPTX, one series of trauma NT placements demonstrated that only about 5% of patients had tension physiology, suggesting that NT placement in the field may not always be required. However, the above evidence is too circumstantial to be generalizable to the overall trauma population. Although NT may temporize tPTX, serious complications occasionally occur. Potential complications of NT include cardiac tamponade, life-threatening bleeding due to pulmonary artery or intercostal vessel injury, nontherapeutic (i.e., ineffective) NT insertion, and nerve injury/neuralgia at the insertion site. Table 1 summarizes reported NT complications collected from various literature sources. There are numerous factors that may contribute to the development of NT-related complications, all of which are discussed below, beginning with anatomic and technical considerations.

ANATOMY AND TECHNIQUE
There are several anatomic locations which have been described as potential sites for NT decompression.
Traditional teaching advocates that a 5 cm 14-G catheter is advanced using “over-the-needle” technique with placement of the needle in the second intercostal space at the midclavicular line. Needle decompression in the anterior axillary line at the second intercostal space has also been proposed due to ease of identification, therapeutic efficacy, reported safety margin, and potentially lower risk of hemorrhage. Other alternative sites for needle decompression include placement at the fourth or fifth intercostal space in the anterior axillary line or at the midaxillary line. These locations are considered suitable for NT since they are also potential sites for subsequent TT insertion as definitive treatment of a PTX. Although there are no compelling data supporting any particular site, it is important to avoid placing NT through a clinically infected site (i.e., area of cellulitis or abscess) on the patient’s skin or chest wall. Figure 1 demonstrates schematic representation of the anatomy around the second intercostal space in the midclavicular line, as well as the other alternative sites for NT placement. In order to avoid information overlap, and minimize any content that is not immediately relevant to the main topic of the current article, the reader is referred to external sources for procedural details of NT placement.

The proximity of the intercostal neurovascular bundle, lung parenchyma, and other surrounding structures may increase the likelihood of iatrogenic injury with blind insertion of a 14-G needle at any given location [Figure 2]. Important is the recognition that the second intercostal space is surrounded by large vascular structures both superiorly and medially [Figure 1]. Of note, the most common bleeding source following NT placement is the lung parenchyma, but bleeding may also occur due to the loss of a tamponade effect from the surrounding chest wall during the separation of the visceral and parietal pleurae, from preexisting adhesive pulmonary disease, or from direct arterial or venous injury. For example, the intercostal arteries and the internal thoracic artery originate from the aorta and the subclavian arteries, creating the potential for brisk bleeding in the setting of iatrogenic injury. Rawlins et al. reported three cases of life-threatening hemorrhage after NT placement at the second intercostal space. In another example, Riwoe and Poncia reported a thoracoscopically-documented injury of the left subclavian artery following NT misplacement into the first intercostal space.

Misidentification of the second intercostal space is quite common. Ferrie et al. performed an observational study of 25 emergency physicians, of whom only 60% (n = 15) have also been described.

Table 1: Summary of NT complications, compiled from various reviews, series, and reports

| Complication                                      | Incidence (%) | Reference |
|--------------------------------------------------|---------------|-----------|
| Never-events and miscellaneous                   |               |           |
| Incorrect patient                                | n/a           | [15]      |
| Wrong side/site procedure                        | n/a           | [15]      |
| Equipment malfunction                            | n/a           | [15]      |
| Inadequate analgesia/sedation                     | n/a           | [15]      |
| Major                                            |               |           |
| Lack of objective clinical improvement            | >90           | [18]      |
| Missed pneumothorax or Ineffective drainage       | 25-50         | [1,6,19-21]| |
| Pneumothorax                                     | 1.8-11        | [18,22]   |
| Hemorrhage                                       | <1            | [22]      |
| Intrathoracic organ injury                        | <1            | [15,23]   |
| Abdominal organ injury                            | <1            | [15,22]   |
| Vascular injury (intercostal, parenchymal, great | <1            | [3,24,25] |
| vessel, central vein, and pulmonary vessel)       |               |           |
| Hemorrhage (significant)                          | <1            | [1,15]    |
| Cardiac injury/tamponade                          | <1            | [1,15]    |
| Neck or chest wall injury                         | n/a           | [15]      |
| Pneumonia/empyema                                 | n/a           | [1,15]    |
| Minor                                            |               |           |
| Pain                                             | 22            | [1,22]    |
| Cough (symptom)                                  | 11            | [21]      |
| Hematoma (minor)                                 | 2             | [1,22]    |
| Fluid collection                                  | <1            | [21]      |
| Skin or cutaneous appendage injury                | n/a           | [15]      |
| Nerve injury (e.g., intercostal)                  | n/a           | [15,17]   |
| Atelectasis                                       | n/a           | [1]       |

Major and minor complications are each listed from most to least common. When available, estimated incidence figures are provided. n/a = Not available.
correctly identified the second intercostal space. Others compared three sites for NT using thoracic computed tomography (CT).\textsuperscript{[12]} The latter comparison included the fifth or sixth intercostal space at the anterior axillary line, the fifth or sixth intercostal space at the mid-axillary line, and a mid-hemithoracic line for needle insertion. It was recommended that NT should be performed at the mid-hemithoracic line [Figure 3] as this site can be easily recognized by the sternal angle and it is far enough removed from the major intrathoracic vascular structures that the risk of iatrogenic injury is smaller.\textsuperscript{[12]}

The risk for bleeding or other complications does not seem to be associated with the clinical setting in which the NT takes place.\textsuperscript{[9,13,26]} Barton et al.,\textsuperscript{[26]} described the use of NTs and TTs by aeromedical crews over a 6-year period, concluding that the risk of bleeding associated with NT was very low, and further reporting that the most common complication was failure of complete chest wall penetration [Figure 2].\textsuperscript{[26]} Consequently, longer catheters and needles may be required to reach the pleural space for decompression in individuals with obese or muscular chest walls.\textsuperscript{[12,32]} At the same time, a balance of sorts needs to be achieved as the use of longer needles may be associated with greater risk of iatrogenic injury and bleeding,\textsuperscript{[12,33]} especially when the NT is “misdirected” [Figure 4]. There is also the potential for intercostal neuralgia after NT placement.\textsuperscript{[34,35]} In a cadaver study, Wraight et al.,\textsuperscript{[36]} found that the neurovascular bundles at the fourth, fifth, and sixth intercostal spaces may not be as protected by the subcostal groove as traditionally taught.

**SPECIFIC COMPLICATIONS**

In subsequent sections, the authors will discuss a number of specific complications of NT, focusing on etiologic factors, diagnostic considerations, and management strategies. The battery of such potential NT complications includes, but is not limited to, iatrogenic PTX, thoracic and abdominal organ injury, vascular injury with associated life-threatening hemorrhage, cardiac tamponade, pain related to the procedure, atelectasis, pneumonia, ineffective drainage of the PTX, and loculated intrapleural hematoma.\textsuperscript{[12]}

**Atelectasis**

There is paucity of documentation on atelectasis as a complication of NT, with most evidence in this area limited to expert opinion.\textsuperscript{[11]} The authors speculate and propose that the presence of pain associated with the NT itself, or any associated traumatic injuries (i.e., rib fractures) may potentially lead to progressive atelectasis. Traditionally, the immediate management of acutely symptomatic tPTX is NT, especially in the prehospital setting.\textsuperscript{[37]} Martin et al.,\textsuperscript{[38]} studied the effectiveness of NT in a swine model, finding that needle thoracostomies had a high rate of failure in the management of PTX or PTX-related physiology, thus indirectly contributing to atelectasis.\textsuperscript{[39]} At the same time, going directly to TT, not only because
of lack of NT efficacy\[39\] but also because of the potential complications of needle decompression, may actually be preferred. However, the presence of pain associated with TT may also be contributory to atelectasis.

**Failure to adequately evacuate PTX**

The primary purpose of needle decompression in a patient with a suspected tPTX is to evacuate ectopic air from the pleural space so that the lung can reexpand and the associated tension physiology can be relieved [Figure 4].\[11\] Overall success rates for NT in pneumothoraces are only between 68 and 75%\[19,20\] and it has been demonstrated that NT frequently fails to evacuate an ongoing, active air leak.\[6,18,39-41\] Cullinane et al.\[6\] questioned the effectiveness of NT, after this intervention failed to effectively decompress the thorax in 50% of patients with physiologic evidence of tPTX, despite apparently adequate catheter length. Failure to evacuate the PTX may be attributed to several factors, including inadequate catheter length, improper placement technique, clot within the catheter, kinking/compression of the catheter, and/or an air leak rate greater than the air evacuation rate by the needle [Figures 2 and 4].\[39,42,43\]

**Insufficient catheter length**

As early as 1990s, it was reported that in a non-trivial proportion of cases, NT failed to adequately evacuate a PTX.\[18\] Ball et al.\[8\] confirmed the association between catheter length and successful decompression by showing that patients who underwent NT with 3.2 cm catheter experienced “failure to decompress” the pleural space 65% of the time (as shown on ultrasound or CT), while those decompressed with a 4.5 cm catheter experienced only a 4% failure rate.\[8\] Britten and Palmer\[40\] analyzed sonographic chest wall thickness in 54 adult patients, with an average thickness being 3.2 cm and a maximum thickness being 5.2 cm. Of note, in 57% of patients the chest wall thickness was >3 cm.\[40\] Based on the above observations, optimal catheter length should be >4.5 cm (e.g., only 4% of patients had chest wall thickness >4.5 cm).\[40\] Other authors presented a case of an inadequately decompressed tPTX in an individual with chest wall thickness that was greater than the 4.5-cm cannula used in that particular scenario. After apparent initial success, the patient deteriorated and definitive air drainage was accomplished only after TT placement.\[41\] Another study described that average chest wall thickness in 604 males and 170 females was approximately 3.5 cm.\[44\] In that report, >19.3% of the men and >35.4% of women had chest wall thickness >4.5 cm.\[44\] Jenkins and Sudheer\[23\] reported a case of a failed decompression of tPTX, where the distance from skin to parietal pleura was approximately 6–7 cm. Therefore, if tPTX is suspected in larger patients, the use of a longer catheter is recommended, with the decompression preferentially performed in the fifth intercostal space, anterior axillary line.\[23\] Commonly available NT catheters are listed in Table 2.

The Advanced Trauma Life Support (ATLS) indication for NT usage is to convert a tPTX into a simple PTX while awaiting definitive placement of a TT.\[10\] Many clinicians and other emergency personnel are forced to attempt NT under difficult circumstances in order to save lives. Under emergent conditions, there is risk for needle misplacement, and thus ineffective intervention or iatrogenic injury [Figures 2 and 4]. Zengerink et al.\[44\] presented retrospective data on chest wall thickness determined on CT in trauma patients, concluding that “standard” catheters used for needle decompression may not reach the pleural space in 10–19% of men and in 25–33% of women.\[44\] Similar results were demonstrated in another study of adult trauma patients, showing that NT using a standard 4.4-cm angiocatheter will be unsuccessful in >50% of patients.\[45\] Inaba et al.\[46\] presented a cadaver-based study concluding that NT placement in the mid-clavicular line at the second intercostal space was successful only 58% of the time using a standard 14-G, 5-cm “catheter-over-needle” device.\[46\] It seems logical that better success would be achieved by placement of a longer catheter for NT attempted in the traditional position of second intercostal space in the midclavicular line. One study examined 6,241 patients, of whom 108 had NT performed in the field. Patients were followed to hospital discharge, with no recorded infection, vascular injury, or bleeding from any of the NTs placed in the prehospital setting.\[18\] Warner et al.\[47\] reported similar findings in 39 NTs, concluding that NT in the prehospital environment was safe.

---

**Table 2: Commonly used needle thoracostomy devices**

| Type                     | Manufacturer                      | Diameter (mm) | Length (mm) | Special features               |
|--------------------------|-----------------------------------|---------------|-------------|-------------------------------|
| Standard IV catheter     | Various                           | 2.1 (14G)     | 50.8        | -                             |
| Air Release System*needle decompression kit | North American Rescue, LLC, Greer, South Carolina, USA | 2.1 (14G) and 3.25 (10G) | 81.2 | Capless flash chamber         |
| H and H*tension pneumothorax decompression needle | H and H Medical Corporation, Ordinary, Virginia, USA | 2.1 (14G)     | 81.2        | Capless flash chamber         |
| Cook® emergency pneumothorax set | Cook Medical, Bloomington, Indiana, USA | 1.83 (15G) | 60          | Chest drain valve             |
| Russell PneumoFix™         | Prometheus DeltaTech, Hope under Dinmore, Herefordshire, UK | 2.64 (12G) | 110         | Veress tipped needle          |
| ThoraQuik™Chest decompression device | MedTree, Donnington Wood Telford Shropshire, UK | 3.12-3.22 mm (~10G) | 100        | Atraumatic needle             |
Ineffective catheter placement
Ineffective catheter placement is the most common complication in patients undergoing NT for tPTX, with associated failure rate of 22–50% according to various studies. Multiple factors contribute to catheter placement failure, including location for catheter placement, chest wall thickness, needle length, and patient characteristics. As stated in previous section, it is classically described that a 5-cm, 14-G catheter is used at the second intercostal space at the midclavicular line. Obese individuals may require the use of longer catheters, especially when considering that average chest wall thickness at the second intercostal space ranges between 38 and 46mm. Moreover, the chest wall is thinner at the axillary location (33–39 mm) than at the midclavicular location. Sanchez et al. recorded that the lateral axillary space chest wall thickness ranges between 52 and 63 mm. Chang et al. demonstrated that a needle length of 8.0 cm is longer than the majority (96%) of chest wall thicknesses measured by CT at the second midclavicular and fourth lateral axillary sites, suggesting that a longer needle length may have a higher success rate for tPTX decompression. With increasing obesity rates, recommendations by the Committee for Tactical Combat Casualty Care favors the use of an 8.0 cm, 14-G needle. and individualization of catheter length should always be considered. Gender may also play a significant role in NT catheter placement as there are important differences in chest anatomy between males and females. Patient arm positioning is also important in the relative contributions of each tissue layer to the overall chest wall thickness.

Risks of NT in patients with chronic obstructive pulmonary disease (COPD)
Spontaneous PTX occurs relatively more frequently in the setting of COPD, including COPD exacerbations. The use of NT in the COPD patient may be especially risky because the “valve-like” effect of physiologic airflow obstruction may produce dynamic lung hyperinflation, in turn increasing the propensity for lung injury during NT placement. The above is of greatest concern in mechanically-ventilated patients, where increasing airway pressures, in conjunction with a PTX, may result in hypoxia, hypotension, and circulatory collapse. A bilateral PTX may also occur because of increased intrathoracic pressures secondary to ventilator redistribution of positive pressure to the opposite lung. If a practitioner suspects a tPTX in a mechanically ventilated patient with COPD, adjustment in ventilatory settings should be immediately considered and chest radiograph performed. Because NT is very likely to produce either a new iatrogenic PTX or exacerbate an existing PTX due to injury of adjacent pulmonary blebs/parenchyma, an intercostal catheter placement using blunt dissection may be a better choice than a “blind” needle decompression in a patient with COPD. At the other end of the spectrum, Mines and Abbuhl reported a case of a patient with COPD in whom a fatal tPTX was altogether missed upon NT placement. The autopsy ultimately revealed that the needle penetrated a noncommunicating bulla in the right upper lobe rather than the pleural space. Similar complications may be difficult to prevent, but ultrasound guidance may be helpful in differentiating bulla from the pleural space.

Hemothorax and life-threatening hemorrhage
As with any other invasive intervention, NT also carries a risk of postprocedural bleeding, including hemothorax and other hemorrhagic complications. Hemorrhage following NT placement is a relatively rare event with only a few cases described. Significant vascular structures located near the second intercostal space include the internal mammary artery and its branches, subclavian vessels, intercostal vessels, and pulmonary arteries. Therefore, if NT placement results in significant immediate blood return from the catheter, or a large hemothorax is seen on the subsequent radiograph, there should be a high suspicion for vascular injury. Using the lateral NT placement approach may help avoid major anterior vascular structures. Of additional importance, postprocedural bleeding may also contribute to nonfunctioning of NT due to blood clot formation within the catheter lumen. A discussion of major vascular and cardiac injury will now follow.

Major vascular and cardiac injury
Rawlins et al. and Butler et al. described life-threatening injuries, including hemothoraces, that complicated the placement of NT. Management included postprocedural resuscitation and surgeries in two cases. However, surgery could not confirm which vascular structures were injured. In another case, a young woman who had a NT placement in the left anterior second intercostal space at midclavicular line was noted to have an immediate sanguineous output of >300 mL. She became hypotensive, requiring immediate fluid resuscitation. A portable chest radiograph showed no residual hemothorax or PTX, but a chest CT demonstrated a large pericardial effusion and fluid in the mediastinum with the catheter tip near the pulmonary artery. The patient was subsequently taken to the operating room, where a 3-mm perforation of the main pulmonary artery was noted, close proximity to the right ventricle. Potential mechanism of major vascular injury has been outlined in Figure 4.

Riwoe and Poncia reported a case of subclavian artery laceration following NT placement in a young female patient. Her initial chest radiography suggested a left tPTX, and a 14-G NT using the “catheter-over-needle” technique was used for decompression in the second intercostal space at the midclavicular line. Repeat radiograph showed resolution of the tPTX. She was then transferred to another facility and arrived with...
ongoing left-sided pleuritic chest pain, dyspnea, pallor, and hypotension of 95/59 mmHg. A second decompression was performed with a 20-Fr tube placed into approximately the third/fourth intercostal space in the midaxillary line, yielding 1,100 mL of blood. The patient was resuscitated with blood products and underwent video-assisted thoracoscopic that revealed hemorrhage from a perforated left subclavian artery. Some authors advocate the use of the mid-hemithorax line instead of the midclavicular line [Figure 3], as well as using the sternal notch as a point of reference for the intercostal level, in order to minimize the risk of major vascular injury.\(^{[25,32]}\) Consequently, close attention to surface anatomy and key landmarks, as well as using the mid-hemithorax as opposed to mid-clavicular line may help mitigate the risk of iatrogenic bleeding. At times, a better alternative may be the use of the fifth midaxillary line as the NT placement site [Figure 1].

**Persistent or recurrent tPTX**

Because NT may result in inadequate drainage of tPTX and persistent or recurrent PTX, an initial rush of air does not reliably confirm proper placement [Figure 2]. In an increasingly obese trauma population, shorter catheter length will likely be insufficient in effectively draining the PTX.\(^{[97]}\) Ultrasound studies have suggested that the traditional site of needle decompression in the second intercostal space, midclavicular line may not be ideal, with substantial proportion of patients having increased chest wall thickness (＞5cm) at this location.\(^{[98]}\) Alternative sites such as the fifth intercostal space at the anterior axillary line should be considered [Figure 1].

A tension PTX can also recur if the catheter becomes dislodged, kinked, blocked, or if the air accumulation rate exceeds the catheter’s ability to evacuate it. Moreover, NT dislodgement may at times be difficult to detect as the catheter may initially slide “in and out” of the plural space. Finally, a catheter that finds its way out of the plural space may “tunnel” or “dissect” into the extrapleural space, while the “elastic” pleura seals at the original puncture site.

**Iatrogenic PTX**

Insertion of NT into the plural space theoretically results in equilibration of pleural and atmospheric pressure. While lifesaving for the patient with tPTX, NT may result in the creation of iatrogenic simple PTX in patients who undergo this procedure unnecessarily. This typically occurs in the setting of decreased breath sounds due to airway obstruction or endotracheal tube misplacement into a mainstem bronchus, but can also happen due to auscultation errors, particularly in a noisy prehospital or trauma bay environment. Hemodynamically stable patients with decreased breath sounds should undergo chest radiography or ultrasound to confirm PTX prior to any attempted procedures. This caution does not apply to the hypotensive trauma patient *in extremis*, with decreased breath sounds, for which NT is appropriate and potentially lifesaving. Simple PTX resulting from NT placement is typically treated with a chest tube. Placement of NT should always be followed by the placement of definitive pleural drain. Having said that, chest tube itself has a substantial complication rate,\(^{[12,99]}\) which must be considered in the overall clinical decision process. Rarely, NT may result in a tPTX. This typically results when the needle penetrates the visceral pleura and lung parenchyma, and may be more common in patients with COPD or intrathoracic adhesions from previous surgery or infection. Isolated needle injury to the lung [Figure 5] typically heals quickly. However, an air leak may be noted after the subsequent TT placement, and such air leak can persist if NT has resulted in rupture of bulla in the emphysematous lung. Rarely, overly deep needle excursion could result in a tracheobronchial injury causing tPTX and a major air leak [Figure 2]. As outlined above, NT should not be placed liberally in patients with known severe bullous emphysema/COPD.\(^{[42]}\)

**Pneumonia and empyema associated with NT**

Occurrence of pneumonia following NT placement has only been reported anecdotally and as an indirect complication of this procedure.\(^{[1,12,99]}\) Barton et al.,\(^{[26]}\) conducted a retrospective study of an aeromedical field experience with NT and TT over a 6-year period.\(^{[26]}\) Out of a total of 9,046 flights, 123 patients received NT in the prehospital phase of the study. Of those 123, 70 patients were ultimately admitted, with six cases of pneumonia reported in the latter group. There were four patients in the NT group who never received TT and were discharged from the hospital, with no complications noted. Another study reported on prehospital NTs performed for suspected PTX (incidence, 1.7% of 6,241 trauma patients). No procedure-related infections were demonstrated.\(^{[18]}\) Another report of prehospital support calls over a 1-year period showed that 39 patients had a NT placed for treatment of tPTX,\(^{[47]}\) among
which 31 were transferred to a trauma center emergency department (ED), with no reported complications related to NT. In another retrospective study of major trauma victims over a 7-year period, 24 patients received NT alone,[7] and the only reported complication was an injury to the lung parenchyma at the site of decompression. It is not inconceivable that a NT placed in a nonsterile fashion may contribute to the genesis of a delayed empyema; however, such an occurrence would likely be underreported.

Oclusion of the NT catheter

Oclusion of the NT may occur secondary to blood, particulate matter, kinking, or tissue entrapment within the catheter.[11,64] Barton et al.[26] retrospectively described initial NT aspirates in 123 patients. These initial aspirates included nothing (40.6% of the NT group), air (32.4%), and air and blood (14.6%), blood (7.4%), lymph, pleural fluid, tissue, and fat (5.0%).[26] Corresponding catheter malfunction was reported in three cases. Conces et al.[43] published a series of 79 patients treated with 84 small caliber (9 French) catheters for pneumothoraces. Seventy-three of these catheters provided definitive treatment of the PTX. Of the 11 that failed, two were due to device kinking in the pleural space and additional two failed due to known occlusion with pleural debris. Another report described three cases of tPTX that failed to respond to NT, with no evidence to suggest that the failure was attributable to physical “plugging” of the lumen, inadequate length of the catheter, or insufficient air flow.[39] The authors attributed these failures to the possibility that flexible, plastic cannulas kinked during their passage through the chest wall. Martin et al.[38] studied the effectiveness of NT versus TT in evacuating tPTX in a swine model, wherein six adult swine underwent creation of tPTX using thoracic CO₂ insufflation via a balloon trocar. In the first arm of the study, 19 tPTX events were treated with NTs; with five failing due to kinking, obstruction, or dislodgment.

Missed localized PTX

undiagnosed and/or untreated PTX may be fatal if tension physiology develops. Reasons for undiagnosed/missed PTX most commonly include clinician/radiologist’s lack of knowledge or experience and inadequate (quality of) radiographic work-up. Pneumothoraces can occur in four different planes on multiview radiographs—anteromedial, subpulmonic, posteromedial, and anterolateral (most common).[21,60,61] A study by Tocino et al.[21] showed that in 88 intensive care unit patients with 112 pneumothoraces, 30% were missed. The most common “missed” pneumothoraces were located in the subpulmonic and anteromedial locations. The incidence of untreated pneumothoraces that evolve into tPTX can be as high as 40%,[1,21,60,61]

At times, pneumothoraces are restricted to certain pleural recesses, which are not amenable to drainage via NT. It has been reported that tPTX can be completely missed during NT placement, resulting in a fatal outcome.[42] In such scenarios, the needle usually fails to enter tPTX but instead is placed into pulmonary bulla, thus not only failing to relieve the tPTX but potentially exacerbating the already emergent clinical scenario.[23,39,42] False pneumothoraces have also been described along the pulmonary ligament.[23,60,61] It is important to be aware of the above pitfalls, and should NT prove inadequate, one should consider a second NT or a TT placement. When permitted by patient condition, proper imaging techniques, such as non-contrast CT of the chest may be warranted.[1,21,39,42,60,61]

INDICATIONS FOR MORE THAN ONE NT

NT may be indicated in anywhere between 1 and 30% trauma patients, depending on the literature cited.[1,8] Lack of expected clinical and/or physiologic response following NT placement may indicate that the initially placed device is ineffective (e.g., due to inadequate catheter length or displacement) and that a second device may be required to adequately evacuate the tPTX. Finally, the traditional approach of NT followed by chest tube placement may at times be re-considered as the standard of care in the management of suspected tPTX, especially when all the procedural supplies are in place and the patient is stable enough to tolerate the slightly longer and more extensive TT procedure.[1,6,26,41] Other reasons for >1 attempt of needle decompression include kinking of the catheter, changes in patient position,[53] clogging or occlusion of the needle due to pleural blood or particles, and catheter dislodgement.

POTENTIAL PITFALLS AND CONDITIONS THAT MIMIC PTX

Certain conditions can mimic the presentation of tPTX, including traumatic/congenital diaphragmatic hernias.[62-68] For example, an unrecognized diaphragmatic rupture has been reported following blunt abdominal trauma with resultant intrathoracic tension physiology.[62] Traumatic diaphragmatic hernias can cause or mimic PTX in a number of ways, including gastric herniation with concurrent distention (e.g., tension gastrothorax) and an unrecognized gastric/bowel herniation into the pleural cavity resulting in bilious leakage and contamination.[62-64] Traumatologists should have a high index of suspicion for a diaphragmatic injury when treating patients with suspected PTX whose chest imaging contains findings that are either unexpected or atypical.[62] Naso/orogastric tube placement is helpful in identifying diaphragmatic injury, especially if post-nasogastric tube placement imaging shows the tube above the level of the diaphragm. It also can be therapeutic by decompressing the stomach,
and thus diminishing the intrathoracic tension. In order to avoid gastric or bowel injury or perforation when managing patients with suspected tPTX and potential diaphragm injury, it is critical to carefully consider all available clinical and radiographic information before intervening procedurally. When possible, skipping NT placement and proceeding directly to definitive TT may be the optimal management maneuver in such situations, mainly because the operator is able to use direct digital inspection of the intrathoracic contents at the tube insertion site prior to advancing the chest tube into the pleural cavity; thus avoiding injury to any surrounding structures, whether thoracic or abdominal.

DISLODGMENT OF NT

Because significant proportion of NTs are placed in the field, catheter dislodgement, and/or kinking poses a problem during patient transport, especially if the NT is not adequately secured. The use of specialized chest seal device(s) may be beneficial in preventing untimely NT dislodgement, especially when the NT is placed in the field. The device described is essentially a protective wound cover that prevents dislodgement until the patient arrives at the definitive care facility. Some authors advocate that if NT fails at the midclavicular line in the second intercostal space, that the subsequent attempt be made at a number of alternative locations [Figure 1].

Patient positioning may play a role in NT dislodgement during transport. Kinking, in and of itself is a problem as significant as is the frequently insufficient catheter length. As previously mentioned, NT lengths <4.5 cm are associated with an increased failure rate compared to catheters ≥5cm, mainly due to greater chest wall thickness in certain patient subpopulations. In summary, the practitioner must be mindful that needle dislodgements do happen, and that one needs to be acutely aware and vigilant of such adverse occurrences during patient transport.

AVENUES FOR FUTURE INVESTIGATION

Despite its relative commonality, NT placement continues to suffer from limited scientific and clinical rationale, as well as from lack of innovative approaches to make this invasive procedure both more effective and safer. One of the innovative approaches reported in recent literature is the use of laparoscopic trocars to perform emergent decompression of tPTX. Although most of the evidence is currently based on animal experimentation, it is certainly conceivable that appropriately modified laparoscopic trocars could provide a safe and reliable alternative to the existing catheter device options. Another avenue of innovation in this important area is the use of modified NT catheters, with one example of such a device having been described by Wayne and McSwain. Finally, ultrasound guidance may help confirm the diagnosis of tPTX and ensure that the needle decompression is performed accurately and safely (provided that sonographic equipment is immediately available and the operator is skilled in sonographic-guided NT catheter placement).

CONCLUSIONS

NT is a life-saving procedure intended to emergently evacuate a tPTX and to temporize the injured patient until the placement of TT can be undertaken. Because it is an invasive procedure that is performed emergently, NT can be associated with a number of complications, some of which may be very severe and even potentially life-threatening. Due to relatively common use of this procedure, it is important that healthcare providers are familiar with, and ready to effectively address, potential complications of NT.

REFERENCES

1. Leigh-Smith, S. Harris T. Tension pneumothorax—time for a re-think? Emerg Med J 2005;22:8-16.
2. Butler KL, Best IM, Weaver WL, Bumpers HL. Pulmonary artery injury and cardiac tamponade after needle decompression of a suspected tension pneumothorax. J Trauma 2003;54:610-1.
3. Rawlins R, Brown KM, Carr CS, Cameron CR. Life threatening haemorrhage after anterior needle aspiration of pneumothoraces. A role for lateral needle aspiration in emergency decompression of spontaneous pneumothorax. Emerg Med J 2003;20:383-4.
4. Carney M, Ravin CE. Intercostal artery laceration during thoracocentesic: Increased risk in elderly patients. Chest 1979;75:520-2.
5. Holloway VJ, Harris JK. Spontaneous pneumothorax: Is it under tension? J Accid Emerg Med 2000;17:222-3.
6. Cullinane DC, Morris JA Jr, Bass JG, Rutherford EJ. Needle thoracostomy may not be indicated in the trauma patient. Injury 2001;32:749-52.
7. Davis DP, Petit K, Rom CD, Poste JC, Sise MJ, Hoyt DB, et al. The safety and efficacy of prehospital needle and tube thoracostomy by aeromedical personnel. Prehosp Emerg Care 2005;9:191-7.
8. Ball CG, Wyzykowski AD, Kirkpatrick AW, Dente CJ, Nicholas JM, Salomone JP, et al. Thoracic needle decompression for tension pneumothorax: Clinical correlation with catheter length. Can J Surg 2010;53:184-8.
9. York D, Dudek L, Larson R, Marshall W, Dries D. A comparison study of chest tube thoracostomy: Air medical crew and in-hospital trauma service. Air Med J 1993;12:227-9.
10. American College of Surgeons Committee on Trauma. Advanced trauma life support for doctors ATLS: Manuals for coordinators and faculty: Eight Ed. 2008, Chicago: American College of Surgeons.
11. Butler FK Jr, Hagmann J, Butler EG. Tactical combat casualty care in special operations. Mil Med 1996;161:3-16.
12. Kwiat M, Tarbox A, Seamon MJ, Swaroop M, Cipolla J, Allen C, et al. Thoracostomy tubes: A comprehensive review of complications and related topics. Int J Crit Illn Inj Sci 2014;4:143-55.
13. Waydhas C, Sauerland S. Pre-hospital pleural decompression and chest tube placement after blunt trauma: A systematic review. Resuscitation 2007;72:11-25.
14. Netto FA, Shulman H, Rizoli SB, Tremblay LN, Brenneman F, Tien H. Are needle decompressions for tension pneumothoraces being performed appropriately for appropriate indications? Am J Emerg Med 2008;26:597-602.
15. Connors KM and Terndrup TE. Chapter 30: Tube thoracostomy and
needle decompression of the chest. In H enretig FM, King C. (Eds). Textbook of pediatric emergency procedures: Chapter 29. Henretig FM and King C. (Eds). Baltimore: Williams and Wilkins. xxxii; 1996. pp. 389–405.

16. Givens ML, Ayotte K, Manifold C. Needle thoracocentesis: Implications of computed tomography chest wall thickness. Acad Emerg Med 2004;11:211-3.

17. Heng K, Bystrzycki A, Fitzgerald M, Gocentas R, Bernard S, Niggemeyer L, et al. Complications of intercostal catheter insertion using EMST techniques for chest trauma. ANZ J Surg 2004;74:420-3.

18. Eckstein M, Suyehara D. Needle thoracostomy in the prehospital setting. Prehosp Emerg Care 1998;3:132-5.

19. Jenkins C, Sudheer PS. Needle thoracocentesis fails to diagnose a large pneumothorax. Anaesthesia 2005;55:925-6.

20. Ng AW, Chan KW, Lee SK. Simple aspiration of pneumothorax. Singapore Med J 1994;35:50-2.

21. Tocino IM, Miller MH, Fairfax WR. Distribution of pneumothorax in the supine and semirecumbent critically ill adult. AJR Am J Roentgenol 1985;144:901-5.

22. Emergent needle decompression of the chest. 2006. Available from: http://healthcare-professionals.sw.org/resources/docs/authorized/ome/emergentneedledecompression2.pdf [Last accessed on 2015 Mar 01].

23. Jenkins CJ, Sudheer PS. Needle thoracocentesis fails to diagnose a large pneumothorax. Anaesthesia 2005;55:925-6.

24. Bjerke HS, Gelb J. Tension pneumothorax. 2002. Available from: http://iranianpda.net/medscape/A432979/business.html#ao1 [Last accessed on 2015 Mar 01].

25. Riowe D, Poncia HD. Subclavian artery laceration: A complication of needle thoracocentesis. Emerg Med Australas 2011;23:651-3.

26. Barton ED, Epperson M, Hoyt DB, Fortlage D, Rosen P. Prehospital access with aeromedical crews. J Emerg Med 1995;13:155-63.

27. Kharod CU, Mabry RL. Needle decompression for tension pneumothorax. Emerg Med Australas 2011;23:651-3.

28. Etoch SW, Bar-Natan MF, Miller FB, Richardson JD. Tube thoracostomy: A 4-month follow-up study with psychophysical examination. Clin Anat 2005;18:471-80.

29. Ciult C, Buxton J, Blackwell T, Schwartz D, Argenta A, et al. Needle thoracostomy for tension pneumothorax: Failure predicted by chest computed tomography. Prehosp Emerg Care 2009;13:14-7.

30. Inaba K, Branco BC, Eckstein M, Shatz DV, Martin MJ, Green DJ, et al. Optimal positioning for emergent needle thoracostomy: A cadaver-based study. J Trauma 2011;71:1099-105.

31. Warner KJ, Copass MK, Bulger EM. Paramedic use of needle thoracostomy in the prehospital environment. Prehosp Emerg Care 2008;12:162-8.

32. Sanchez LD, Straszewski S, Saghir A, Khan A, Horn E, Fischer C, et al. Anterior versus lateral needle decompression of tension pneumothorax: Comparison by computed tomography chest wall measurement. Acad Emerg Med 2011;18:1022-6.

33. Powers WF, Clancy TV, Adams A, West TC, Kotwall CA, Hope WW. Proper catheter selection for needle thoracostomy: A height and weight-based criteria. Injury 2014:45:107-11.

34. American College of Surgeons Committee on Trauma. 2013. Prehospital trauma life support. Seventh edition.

35. Command, U.S.S.O., U.S. Special Operations Command tactical trauma protocols, tactical medical emergency protocols, and canine tactical combat casualty care (C-TCC) for special operations advanced tactical practitioners. J Spec Oper Med 2012:2-242.

36. Beckett A, Savage E, Pannell D, Acharya S, Kirkpatrick A, Tien HC. Needle decompression for tension pneumothorax in tactical combat casualty care: Do catheters placed in the midaxillary line kink more often than those in the midclavicular line? J Trauma 2011;71:5408-12.

37. Garner DJ, Tuxen D, Asthma and chronic obstructive pulmonary disease in the intensive care unit. Anaesthesia Intensive Care Med 2010;11:481-6.

38. Bowling D, Degiannis E, Westaby S. Thoracic injury: In Ballistic Trauma: A Practical Guide; Mahoney PF, Ryan J, Brooks A, and Schwab CW (Eds.); 2005. p. 241-69.

39. Evans DC, Stawicki SP, Davido HT, Eiferman D. Obesity in trauma patients: Correlations of body mass index with outcomes, injury patterns, and complications. Am Surg 2011;77:1003-8.

40. Inaba KI, Ives C, McClure K, Branco BC, Eckstein M, Shatz D, et al. Radiologic evaluation of alternative sites for needle decompression of tension pneumothorax. Arch Surg 2012;147:813-8.

41. Etoch SW, Bar-Natan MF, Miller FB, Richardson JD. Tube thoracostomy: Factors related to complications. Arch Surg 1995;130:521-5.

42. Lams PM, Jolles H. The effect of lobar collapse on the distribution of free intrapleural air. Radiology 1979;133:593‑5.

43. Garcia J, Libowitz AB. Radiologic assessment of potential sites for needle decompression of tension pneumothorax: Failure predicted by chest computed tomography. Prehosp Emerg Care 2009;13:14-7.

44. Inaba K, Branco BC, Eckstein M, Shatz DV, Martin MJ, Green DJ, et al. Optimal positioning for emergent needle thoracostomy: A cadaver-based study. J Trauma 2011;71:1099-105.

45. Warner KJ, Copass MK, Bulger EM. Paramedic use of needle thoracostomy in the prehospital environment. Prehosp Emerg Care 2008;12:162-8.

46. Sanchez LD, Straszewski S, Saghir A, Khan A, Horn E, Fischer C, et al. Anterior versus lateral needle decompression of tension pneumothorax: Comparison by computed tomography chest wall measurement. Acad Emerg Med 2011;18:1022-6.

47. Chang SJ, Ross SW, Kierje DJ, Anderson WE, Rogers AT, Sing RF, et al. Evaluation of 8.0-cm needle at the fourth anterior axillary line for needle chest decompression of tension pneumothorax. J Trauma Acute Care Surg 2014;76:1029-34.

48. Akoglu H, Akoglu EU, Erman S, Akoglu T, Altinkon AD, Gunesel O, et al. Determination of the appropriate catheter length and place for needle thoracostomy by using computed tomography scans of pneumothorax patients. Injury 2013:44:1177-82.

49. Powers WF, Clancy TV, Adams A, West TC, Kotwall CA, Hope WW. Proper catheter selection for needle thoracostomy: A height and weight-based criteria. Injury 2014:45:107-11.

50. American College of Surgeons Committee on Trauma. 2013. Prehospital trauma life support. Seventh edition.

51. Command, U.S.S.O., U.S. Special Operations Command tactical trauma protocols, tactical medical emergency protocols, and canine tactical combat casualty care (C-TCC) for special operations advanced tactical practitioners. J Spec Oper Med 2012:2-242.

52. Beckett A, Savage E, Pannell D, Acharya S, Kirkpatrick A, Tien HC. Needle decompression for tension pneumothorax in tactical combat casualty care: Do catheters placed in the midaxillary line kink more often than those in the midclavicular line? J Trauma 2011;71:5408-12.

53. Garner DJ, Tuxen D, Asthma and chronic obstructive pulmonary disease in the intensive care unit. Anaesthesia Intensive Care Med 2010;11:481-6.

54. Bowling D, Degiannis E, Westaby S. Thoracic injury: In Ballistic Trauma: A Practical Guide; Mahoney PF, Ryan J, Brooks A, and Schwab CW (Eds.); 2005. p. 241-69.

55. Evans DC, Stawicki SP, Davido HT, Eiferman D. Obesity in trauma patients: Correlations of body mass index with outcomes, injury patterns, and complications. Am Surg 2011;77:1003-8.

56. Inaba KI, Ives C, McClure K, Branco BC, Eckstein M, Shatz D, et al. Radiologic evaluation of alternative sites for needle decompression of tension pneumothorax. Arch Surg 2012;147:813-8.

57. Etoch SW, Bar-Natan MF, Miller FB, Richardson JD. Tube thoracostomy: Factors related to complications. Arch Surg 1995;130:521-5.

58. Lams PM, Jolles H. The effect of lobar collapse on the distribution of free intrapleural air. Radiology 1982;142:309-12.

59. Rhea JT, vanSonnenberg E, McCloud TC. Basilar pneumothorax in the supine adult. Radiology 1979;133:593-5.

60. Schwab RJ, Jarvik JC. Tension pneumothorax secondary to a gastrointestinal fistula in a traumatic diaphragmatic hernia. Chest 1991;99:247-9.

61. Newman MJ. A mistaken case of tension pneumothorax. BMJ Case Rep 2014;2014.
Wernick, et al.: Complications of needle thoracostomy

64. Radin DR, Ray MJ, Halls JM. Strangulated diaphragmatic hernia with pneumothorax due to colopleural fistula. AJR Am J Roentgenol 1986;146:321-2.
65. Lernau O, Bar-Maor JA, Nissan S. Traumatic diaphragmatic hernia simulating acute tension pneumothorax. J Trauma 1974;14:880-4.
66. Reddy SA, Vemuru R, Padmanabhan K, Steinheber FU. Colopleural fistula presenting as tension pneumothorax in strangulated diaphragmatic hernia. Report of a case. Dis Colon Rectum 1989;32:165-7.
67. Lindskog GE, Lawrence EA. The treatment of thoracogastric fistula. J Thorac Surg 1947;16:477-83.
68. Markowitz AM, Herter FP. Gastro-pleural fistula as a complication of esophageal hiatal hernia. Ann Surg 1960;152:129-34.
69. Allison K, Porter KM, Mason AM. Use of the Asherman chest seal as a stabilisation device for needle thoracostomy. Emerg Med J 2002;19:590-1.
70. Pattison GT. Needle thoracocentesis in tension pneumothorax: Insufficient cannula length and potential failure. Injury 1996;27:758.
71. Hatch Q, Debarros M, Johnson E, Inaba K, Martin M. Standard laparoscopic trocars for the treatment of tension pneumothorax: A superior alternative to needle decompression. J Trauma Acute Care Surg 2014;77:170-5.
72. Wayne MA, McSwain NE Jr. Clinical evaluation of a new device for the treatment of tension pneumothorax. Ann Surg 1980;191:760-2.
73. Stawicki SP, Bahrner DP. Modern sonography and the bedside practitioner: Evolution of ultrasound from curious novelty to essential clinical tool. Eur J Trauma Emerg Surg 2014.
74. Bahn DP, Evans DC, Lindsey DE, Stawicki SP. What's New in Critical Illness and Injury Science? The challenge of verifying tracheal airway placement: Solving the puzzle one piece at a time. Int J Crit Illn Inj Sci 2013;3:105-7.

Cite this article as: Wernick B, Hon HH, Mubang RN, Cipriano A, Hughes R, Rankin DD, et al. Complications of needle thoracostomy: A comprehensive clinical review. Int J Crit Illn Inj Sci 2015;5:160-9.

Source of Support: Nil, Conflict of Interest: None declared.