Risk of Harm in Needle Decompression for Tension Pneumothorax

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ABSTRACT

Introduction: Tension pneumothorax (TPX) is the third most common cause of preventable death in trauma. Needle decompression at the fifth intercostal space at anterior axillary line (5th ICS AAL) is recommended by Tactical Combat Casualty Care (TCCC) with an 83-mm needle catheter unit (NCU). We sought to determine the risk of cardiac injury at this site. **Methods:** Institutional data sets from two trauma centers were queried for 200 patients with CT chest. Inclusion criteria include body mass index of ≤30 and age 18–40 years. Measurements were taken at 2nd ICS mid clavicular line (MCL), 5th ICS AAL and distance from the skin to pericardium at 5th ICS AAL. Groups were compared using Mann-Whitney U and chi-squared tests. **Results:** The median age was 27 years with median BMI of 23.8 kg/m^2. The cohort was 69.5% male. Mean chest wall thickness at 2nd ICS MCL was 38-mm (interquartile range (IQR) 32–45). At 5th ICS AAL, the median chest wall thickness was 30-mm (IQR 21–40) and the distance from skin to pericardium was 66-mm (IQR 54–79). **Conclusion:** The distance from skin to pericardium for 75% of patients falls within the length of the recommended needle catheter unit (83-mm). The current TCCC recommendation to "hub" the 83mm needle catheter unit has potential risk of cardiac injury.

KEYWORDS: *pneumothorax; needle thoracentesis; battlefield trauma*

Introduction

Tension pneumothorax (TPX) is considered one of the three primary causes of preventable death from trauma, following hemorrhage (91%) and airway obstruction (8%), with a mortality of 1.1%. These statistics were obtained from a 10-year review of battlefield fatalities published by Eastridge et al. in 2012.[1]

The pathophysiology of TPX is secondary to an accumulation of air in the pleural space above atmospheric pressure due to an injured lung and the resultant "air leak." This air leak collapses the lung, and the increase in intrapleural and intrathoracic pressure reduces cardiac output secondary to decreased right atrial filling. This leads to an obstructive shock and results in cardiac arrest unless aggressively managed.[2]

The emergency treatment of this pathology is a thoracentesis, usually using a needle, which is known as needle decompression (NDC). NDC acts to relieve the build-up of pressure in the pleural space by allowing gas to escape through the needle and cannula. Two locations are recommended for this procedure: a) the 2nd intercostal space at the midclavicular line (2nd ICS MCL), which has been the classic teaching, and b) more recently, the 5th intercostal space at the anterior axillary line (5th ICS AAL), which is now recommended by Tactical Combat Casualty Care (TCCC) (Figure 1).[3]

Following concerns that the shorter intravenous (IV) cannula did not have the length required to reach the pleural space, a recommendation was made by the Committee on TCCC (CoTCCC) to use longer needles.[4] The current TCCC guideline recommendation is "decompress the chest on the side of the injury with a 14-gauge or a 10-gauge, 3.25-inch (82.5-mm) needle/catheter unit."[2] The procedure is described as "insert the needle/catheter unit all the way to the hub and hold it in place for 5–10 seconds to allow decompression to occur."[3]

When performing an NDC on the left using the left lateral 5th ICS AAL, there is a potential for injury to the heart from the initial hubbing of the 83-mm NCU. This risk is likely underestimated. To better assess the potential for iatrogenic harm, an anatomic analysis was designed using cross-sectional imaging

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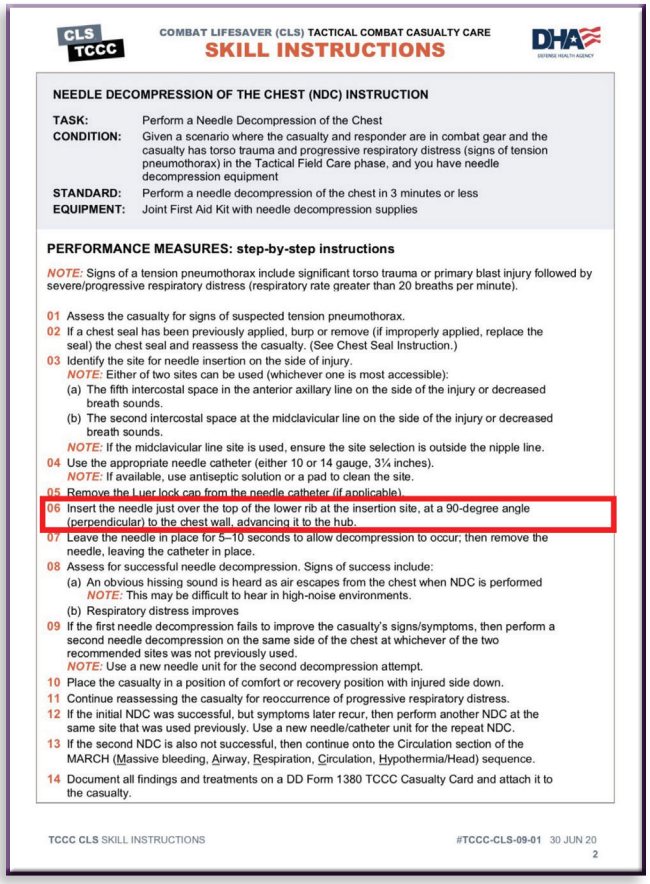
FIGURE 1 *TCCC CLS skill instruction: Needle decompression of the chest (NDC) instruction.*



CLS TCCC

COMBAT LIFESAVER (CLS) TACTICAL COMBAT CASUALTY CARE

SKILL INSTRUCTIONS

DHA

NEEDLE DECOMPRESSION OF THE CHEST (NDC) INSTRUCTION

TASK: Perform a Needle Decompression of the Chest

CONDITION: Given a scenario where the casualty and responder are in combat gear and the casualty has torso trauma and progressive respiratory distress (signs of tension pneumothorax) in the Tactical Field Care phase, and you have needle decompression equipment

STANDARD: Perform a needle decompression of the chest in 3 minutes or less

EQUIPMENT: Joint First Aid Kit with needle decompression supplies

PERFORMANCE MEASURES: step-by-step instructions

NOTE: Signs of a tension pneumothorax include significant torso trauma or primary blast injury followed by severe/progressive respiratory distress (respiratory rate greater than 20 breaths per minute).

01 Assess the casualty for signs of suspected tension pneumothorax.
02 If a chest seal has been previously applied, burp or remove (if improperly applied, replace the seal) the chest seal and reassess the casualty. (See Chest Seal Instruction.)
03 Identify the site for needle insertion on the side of injury.
NOTE: Either of two sites can be used (whichever one is most accessible):
(a) The fifth intercostal space in the anterior axillary line on the side of the injury or decreased breath sounds.
(b) The second intercostal space at the midclavicular line on the side of the injury or decreased breath sounds.
NOTE: If the midclavicular line site is used, ensure the site selection is outside the nipple line.
04 Use the appropriate needle catheter (either 10 or 14 gauge, 3¼ inches).
NOTE: If available, use antiseptic solution or a pad to clean the site.
05 Remove the Luer lock cap from the needle catheter (if applicable).
06 Insert the needle just over the top of the lower rib at the insertion site, at a 90-degree angle (perpendicular) to the chest wall, advancing it to the hub.
07 Leave the needle in place for 5–10 seconds to allow decompression to occur, then remove the needle, leaving the catheter in place.
08 Assess for successful needle decompression. Signs of success include:
(a) An obvious hissing sound is heard as air escapes from the chest when NDC is performed
NOTE: This may be difficult to hear in high-noise environments.
(b) Respiratory distress improves
09 If the first needle decompression fails to improve the casualty's signs/symptoms, then perform a second needle decompression on the same side of the chest at whichever of the two recommended sites was not previously used.
NOTE: Use a new needle unit for the second decompression attempt.
10 Place the casualty in a position of comfort or recovery position with injured side down.
11 Continue reassessing the casualty for reoccurrence of progressive respiratory distress.
12 If the initial NDC was successful, but symptoms later recur, then perform another NDC at the same site that was used previously. Use a new needle/catheter unit for the repeat NDC.
13 If the second NDC is also not successful, then continue onto the Circulation section of the MARCH (Massive bleeding, Airway, Respiration, Circulation, Hypothermia/Head) sequence.
14 Document all findings and treatments on a DD Form 1380 TCCC Casualty Card and attach it to the casualty.

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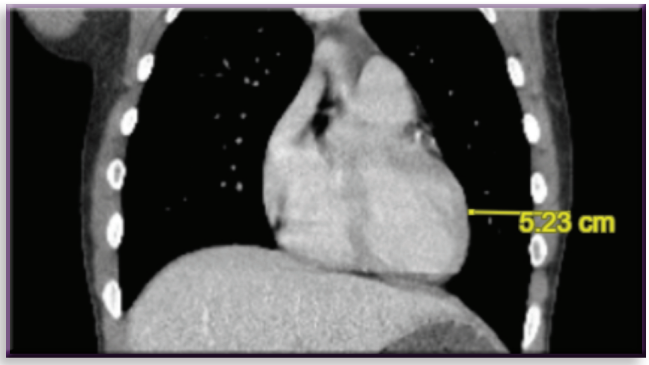
to understand this possibility and to inform current and future guidelines for the treatment of tension PTX.

Methods

After Institutional Review Board exemption at University of Texas Health, San Antonio, TX and St. Lukes University Health Network, Bethlehem, PA, institutional datasets from an American College of Surgeons verified level I trauma center and a Pennsylvania Trauma System Foundation state-verified Level 1 trauma center were included in this analysis. The registries from these two trauma centers were queried for patients who had undergone a CT scan of the chest for a traumatic injury from 1 January 2016 to 1 January 2021. Exclusion criteria included an intrathoracic mass or lesion. Inclusion criteria consisted of body mass index (BMI) of ≤30 and age between 18 and 40 years, with both male and female sexes included. At both institutions, patient data were obtained from the trauma registry by random selection of 100 patients who met inclusion criteria. However the patient's sex, age, and BMI were blind to the data collector. One surgeon collector reviewed the images at each institution with a third surgeon reviewing the collection process across both institutions to ensure measurements were taken in the same manner. Measurements were taken on CT scans of the chest including the chest wall thickness at the 2nd ICS at MCL, the 5th ICS at AAL, and the distance from the skin to the pericardium at 5th ICS at AAL. AAL was defined as the lateral border of the pectoralis musculature. The anterior border of the pectoralis major muscle was identified in the axial plane and the corresponding coronal plane was then used for measurement for the 5th ICS AAL. The 2nd ICS was likewise identified in the axial plane, and a measurement taken in the matched sagittal plane for the 2nd ICS MCL. Measurements were taken in a perpendicular plane to the skin, at the inferior border of the space (Figure 2). Data were reported by determining median and interquartile range (IQR). The data were then analyzed based on patient sex, with comparison of non-normally distributed continuous variables using the Mann-Whitney U test, with normality determined by Shapiro-Wilk test.

FIGURE 2 *Sample measurement at 5th ICS AAL in the coronal plane.*



Results

In total, 200 CT scans were reviewed between the two institutions: 100 patients from UT Health San Antonio, San Antonio, TX and 100 patients from St. Luke's University Health Network, Bethlehem, PA. Demographics and measurements for the composite group are outlined in Table 1. Overall, the median age was 27 years (IQR 22.0–33.8) with a median BMI of 23.8 kg/m^2 (IQR 21.8–27.2). The cohort was 69.5% male (n = 139) and 30.5% female (n = 61). Mean chest wall thickness at 2nd ICS MCL was 38-mm (IQR 32–45). At the 5th ICS AAL, the median chest wall thickness was 30-mm (IQR 21–40), and the distance from skin to pericardium was 66-mm (IQR 54–79). Comparative demographics and measurements for males versus females are outlined in Table 2.

TABLE 1 *Demographic and Measurement Values for Entire Cohort*

Demographics	Cohort (n = 200)
Median Age, year (IQR)	27 (22.0–33.8)
Median BMI, kg/m^2 (IQR)	23.8 (21.8–27.2)
Median Chest Wall Thickness, 2nd ICS MCL, mm (IQR)	38 (32–45)
Median Chest Wall Thickness, 5th ICS AAL, mm (IQR)	30 (21–40)
Median Skin to Pericardium Distance, 5th ICS AAL, mm (IQR)	66 (54–79)

IQR = interquartile range, BMI = body mass index.

There were no statistically significant differences for males versus females with respect to any demographic or measurement parameter. The median ages for males and females were 26.0 (IQR 22.0–34.0) versus 29.0 years (IQR 21.5–34.0) (p = .76) with a median BMI of 24.0 (IQR 21.5–27.4) versus 23.5 kg/m^2 (IQR 19.7–26.6) (p =.17), respectively. Chest wall thickness measurements did not vary between males and females with median 2nd ICS MCL measurements of 39-mm (IQR 32–45) versus 38-mm (IQR 32–47) (p =.45) and 5th ICS AAL measurements of 29 (IQR 21–38) versus 34-mm (IQR 23–43) (p =.07), respectively. There were no differences in median distances from skin to pericardium for males or

TABLE 2 *Demographic and Measurement Values for Male Versus Females*

	Males (n = 139)	Females (n = 61)	*p*-value
Median Age, year (IQR)	26.0 (22.0–33.0)	29.0 (21.5–34.0)	0.76
Median BMI, kg/m^2 (IQR)	24.0 (21.5–27.4)	23.5 (19.7–26.6)	0.17
Median Chest Wall Thickness, 2nd ICS MCL, mm (IQR)	39 (32–45)	38 (32–47)	0.45
Median Chest Wall Thickness, 5th ICS AAL, mm (IQR)	29 (21–38)	34 (23–43)	0.07
Median Skin to Pericardium Distance, 5th ICS AAL, mm (IQR)	65 (53–79)	69 (59–80)	0.13

IQR = interquartile range, BMI = body mass index.

females at 5th ICS AAL with 65-mm (IQR 53–79) versus 69-mm (IQR 59–80) (p =.13), respectively.

Discussion

This analysis indicates that there is a risk of cardiac injury when treating a left-sided tension PTX in non-obese individuals if an 83-mm NCU is used at the 5th ICS at the AAL. These data, obtained from a random sampling of 200 CT scans from urban trauma centers, demonstrated that the median distance from the skin to the heart was 66-mm (2.5 in) in those with a BMI of 24. Thus, the data indicate that in the non-obese patient, 75% of the time there could be a potential cardiac injury with NDC of the left chest with an 83-mm NCU.

Our analysis does not demonstrate a difference between sexes when it comes to potential injury of the heart when a left-sided NDC is performed; 75% of both males and females are at risk for cardiac injury with an 83-mm needle. One of the reasons that the left 5th ICS AAL was chosen by the CoTCCC was because this is an area with less muscle on the chest wall and therefore a better chance of effective decompression of a life-threatening T-PTX. Fully inserting, or "hubbing," the NCU as described in TCCC carries anatomic risk of injury to the heart at the 5th ICS AAL.

It should also be noted that as the TCCC procedure calls for leaving the needle in, thus the cutting edge of the needle is in place to cut or puncture cardiac structures. Further, there is often a tissue plug picked up by the needle, and, unless this is expelled, the gas cannot escape through the needle as recommended by TCCC. In this case, leaving the needle in place only serves to increase the risk of potential injury to the heart while not allowing functional decompression of the pleural space.

There are several limitations to this study. First, this is a retrospective review of CT imaging that was not collected in an identical fashion. While the overall CT scan protocols at both institutions are similar, they are not identical, and patient positioning was not globally standardized. Next, while this population mirrors a military population, the patients are civilians. A dataset of military trauma center patients was examined in preparation for this study. However, the dataset contained measurements at different levels, and the patient demographics did not match that at the two civilian institutions with a higher number of geriatric patients and obese patients, which mandated exclusion. We plan to conduct an additional study with equally matched patients and similar measurement protocol in a military population to further contribute to this body of literature.

No matter which anatomical location is chosen, there are safer alternative techniques that emphasize not advancing the needle any deeper than entry into the pleural space. One method is attaching a half fluid filled syringe to the NCU. When advancing the needle through the tissues towards the lung, ensure there is negative pressure in the chamber of the syringe by pulling backwards on the plunger. As the NCU enters the pleural space there is rapid identification of the presence of gas (TPX) by the escaping gas bubbles that are immediately visible in the syringe, along with a release of negative pressure. At this point the catheter *only* may be advanced. This technique has the benefit of both confirmation of the diagnosis of the PTX and treatment, simultaneously. An alternative technique not requiring extra equipment is to advance the NCU no further than half the length of the needle into the tissues, from which point the catheter *only* is advanced, which is unlikely to cause damage. The size of the patient also needs to be considered, with larger individuals having either greater muscle mass or more subcutaneous fat, and therefore more of the NCU may be required to reach the pleural space. However, smaller individuals with less subcutaneous fat are at specific risk with the current TCCC guidelines. In either setting, an 83-mm NCU is too long if "hubbed" to provide a distinct benefit for any patient evaluated in this study and using the full length of the needle catheter unit should likely be reserved for obese patients with significant chest or flank tissue.

Conclusion

Needle decompression for tension pneumothorax is a potentially lifesaving intervention. However, there is also a risk of harm from this procedure. Providers should attempt to minimize the risk of harm to the patient. The authors suggest that the current TCCC guideline recommendation for "hubbing" the NCU on the left lateral 5th ICS AAL position should be reviewed with possible adjustments in technique to make the procedure safer. The avoidance of harm to our patients should remain our highest priority.

Author Contributions

PT and MB conceived the study concept and study design. AC and EH performed data acquisition, and MB performed data analysis. JG, JB, SN, and DH provided operational support for data acquisition and analysis. PT, CB, JB, EG, JG, AH, DJ, SN, GS, and MB provided critical revision and editing with all authors approving the final manuscript.

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Disclosure

None.

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