Management of Suspected Tension Pneumothorax in Tactical Combat Casualty Care

TCCC Guidelines Change 17-02

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ABSTRACT

This change to the Tactical Combat Casualty Care (TCCC) Guidelines that updates the recommendations for management of suspected tension pneumothorax for combat casualties in the prehospital setting does the following things: (1) Continues the aggressive approach to suspecting and treating tension pneumothorax based on mechanism of injury and respiratory distress that TCCC has advocated for in the past, as opposed to waiting until shock develops as a result of the tension pneumothorax before treating. The new wording does, however, emphasize that shock and cardiac arrest may ensue if the tension pneumothorax is not treated promptly. (2) Adds additional emphasis to the importance of the current TCCC recommendation to perform needle decompression (NDC) on both sides of the chest on a combat casualty with torso trauma who suffers a traumatic cardiac arrest before reaching a medical treatment facility. (3) Adds a 10-gauge, 3.25-in needle/catheter unit as an alternative to the previously recommended 14-gauge, 3.25-in needle/catheter unit as recommended devices for needle decompression. (4) Designates the location at which NDC should be performed as either the lateral site (fifth intercostal space [ICS] at the anterior axillary line [AAL]) or the anterior site (second ICS at the midclavicular line [MCL]). For the reasons enumerated in the body of the change report, participants on the 14 December 2017 TCCC Working Group teleconference favored including both potential sites for NDC without specifying a preferred site. (5) Adds two key elements to the description of the NDC procedure: insert the needle/catheter unit at a perpendicular angle to the chest wall all the way to the hub, then hold the needle/catheter unit in place for 5 to 10 seconds before removing the needle in order to allow for full decompression of the pleural space to occur. (6) Defines what constitutes a successful NDC, using specific metrics such as: an observed hiss of air escaping from the chest during the NDC procedure; a decrease in respiratory distress; an increase in hemoglobin oxygen saturation; and/or an improvement in signs of shock that may be present. (7) Recommends that only two needle decompressions be attempted before continuing on to the "Circulation" portion of the TCCC Guidelines. After two NDCs have been performed, the combat medical provider should proceed to the fourth element in the "MARCH" algorithm and evaluate/treat the casualty for shock as outlined in the Circulation section of the TCCC Guidelines. Eastridge's landmark 2012 report documented that noncompressible hemorrhage caused many more combat fatalities than tension pneumothorax.[1] Since the manifestations of hemorrhagic shock and shock from tension pneumothorax may be similar, the TCCC Guidelines now recommend proceeding to treatment for hemorrhagic shock (when present) after two NDCs have been performed. (8) Adds a paragraph to the end of the Circulation section of the TCCC Guidelines that calls for consideration of untreated tension pneumothorax as a potential cause for shock that has not responded to fluid resuscitation. This is an important aspect of treating shock in combat casualties that was not presently addressed in the TCCC Guidelines. (9) Adds finger thoracostomy (simple thoracostomy) and chest tubes as additional treatment options to treat suspected tension pneumothorax when further treatment is deemed necessary after two unsuccessful NDC attempts—if the combat medical provider has the skills, experience, and authorizations to perform these advanced interventions and the casualty is in shock. These two more invasive procedures are recommended only when the casualty is in refractory shock, not as the initial treatment.

KEYWORDS: *guidelines; tension pneumothorax; Tactical Combat Casualty Care*

[1–31]Please see page 35.

Proximate Reasons for This Proposed Change

A 2008 report from the Canadian military discussing opportunities for improvement in TCCC reported that seven combat casualties were found to have arrived at medical treatment facilities with no vital signs and without having had prehospital NDC performed.[2] TCCC recommends that casualties with torso trauma or polytrauma who suffer a traumatic cardiac arrest have bilateral NDC performed to treat a possible tension pneumothorax.[3,4] There have also been two recent fatalities identified on Joint Trauma System (JTS)/Armed Forces Medical Examiner System (AFMES) preventable death reviews in which the deceased casualty had a tension pneumothorax at autopsy with no other obviously fatal wounds and without NDC having been attempted. Note that the diagnosis of tension pneumothorax at autopsy is made more complex by the absence of observable physiologic effects and by the potential for post-mortem artifact.

The initial manifestation of a developing tension pneumothorax in a spontaneously breathing and conscious casualty is respiratory distress, but an untreated tension pneumothorax may progress beyond respiratory symptoms to circulatory shock and traumatic cardiac arrest. NDC is a rapid and effective means of decompressing a tension pneumothorax, but it is not a completely benign intervention and the procedural risks that it entails require that a reasonable expectation of clinical benefit be present before undertaking the procedure. As a minimum, in the absence of penetrating thoracic trauma, NDC may necessitate the placement of a chest tube in a casualty who would not otherwise have required one. There is also the potential for life-threatening hemothorax as a complication of the procedure. As a result of these considerations, there is some disagreement in the medical literature about when in the sequence of evolving signs/symptoms that NDC for a suspected tension pneumothorax should be undertaken. This report will discuss some of these varying perspectives and will reevaluate the CoTCCC recommendations on this topic.

There is also recent literature reporting that a 14-gauge needle has a high failure rate in some animal models of tension pneumothorax,[5–8] but that is countered by other studies in both animal models and the clinical literature that indicate that the currently recommended device for NDC in TCCC (a 14-gauge, 3.25-inch needle/catheter unit) is adequate.[9–12] This proposed change will evaluate what, if any, action should be taken about the specific device recommended to perform NDC in light of the current evidence. The potential for increased risk of complications when using longer or larger gauge devices must be considered in addition to the expected increased efficacy of these larger gauge devices.

Recent literature suggests that the lateral site (fifth ICS at the AAL) may be the preferred location for NDC.[13–22] The lateral site is currently recommended as the primary site for NDC in Advanced Trauma Life Support (ATLS).[23] Prior to this change, TCCC recommended the anterior site as the primary option for NDC and the lateral site as the alternate location.[3,24]

Finally, the TCCC Guidelines at present do not indicate what constitutes a successful needle decompression, nor do they include a sequence of steps to be undertaken if NDC fails to relieve the signs and/or symptoms of a suspected tension pneumothorax.[25] This has resulted in reported incidents in which repeated NDC attempts (as many as 14) have been performed because the symptoms of respiratory distress have not been relieved by NDC or because they recur after initial improvement.[26,27]

Scenario

A Marine Corps Special Operations unit was conducting a convoy operation in Western Afghanistan. The unit was ambushed in a mountain draw, taking fire from high ground on both sides of the draw. There were 14 casualties sustained in the engagement, including the treating corpsman. One casualty sustained a gunshot wound (GSW) to the left side of the chest. Evacuation of casualties was delayed several hours due to heavy, accurate fire and rocky terrain—a scenario with an unusually long Care Under Fire period. The casualty was subsequently treated with 14 needle decompressions—all performed in the second ICS at the midclavicular line—for suspected tension pneumothorax. The needles and the catheters were both removed approximately 5 seconds after each insertion. The corpsman providing care observed that the casualty had "relief on his face" and improvement of his respiratory distress with each NDC procedure. The NDCs were performed in the supine position, because of the hostile fire as well as the treating corpsman's concerns that sitting the casualty up might worsen his hemodynamic status, given his wounding pattern, which placed him at high risk of internal hemorrhage, which was later confirmed at surgery. The casualty survived his wounds and remained on active duty until his retirement some years later (personal communication – HMCM Jeremy Torrisi, 2008).

BACKGROUND

Tension Pneumothorax Physiology

There is no single, universally accepted definition of tension pneumothorax,[28–31] but all definitions include an injury to the lung that results in air leaking into the pleural space and being trapped there with a secondary increase in intrapleural pressure. Even when these events have occurred and a shift in position of the intrathoracic organs has resulted, however, the patient may remain stable for a time. One case report described a patient with a tension pneumothorax that was found on ultrasound to have caused displacement of the heart into the right hemithorax and yet still appeared clinically stable without significant dyspnea or hypotension.[32]

For the purpose of this review, tension pneumothorax is defined as the accumulation of air under pressure in the pleural space. In the early stages of the process, the casualty can compensate physiologically. Once the individual is no longer able to compensate, however, progressive respiratory failure and/or shock will develop. Traumatic cardiac arrest may ensue if the tension pneumothorax is not treated.

Combat casualties with tension pneumothorax are typically breathing spontaneously, at least for a variable time period, after their injury.[33] Much of the tension pneumothorax literature is based on mechanically ventilated patients.[28,30,31,34] Tension pneumothorax in patients who are being mechanically ventilated may have a more fulminant course than that seen in patients who are breathing spontaneously. To quote one report: "In ventilated patients, (tension pneumothorax) presents rapidly with consistent signs of respiratory and cardiac compromise. In contrast, awake patients show a greater variability

of presentations, which are generally more progressive, with slower decompensation."[31] In a review of 183 tension pneumothorax patients (86 breathing unassisted and 97 receiving assisted ventilation), 50% of spontaneously breathing patients were hypoxic in contrast to 92% of assisted ventilation patients.[28] The incidence of subsequent hypotension and cardiac arrest was 12.6 and 17.7 times greater, respectively, among patients receiving assisted ventilation than in spontaneously breathing patients.[28]

There is also no single definitive animal model for tension pneumothorax. Different studies show variation in methods and definitions.[5,7,8,11,35]

Hypoxemia has been observed to reliably precede the onset of shock in animal models of tension pneumothorax.[29,35] Hypoxemia alone, however, does not typically cause the subjective experience of dyspnea or "air hunger." A review of 27 cases of hypobaric hypoxia reported during aviation operations found that the symptoms of hypoxia were "subtle and often involved cognitive impairment or light-headedness."[36] Hypoxia-related closed-circuit mixed-gas diving accidents that are caused by interruption of the oxygen supply may progress to hypoxic loss of consciousness without producing the sensation of dyspnea.[37] Hypercapnia (carbon dioxide buildup), in contrast, is a potent stimulator of ventilation and does cause increased depth and frequency of respirations and the subjective sensation of dyspnea or "air hunger."[37] Hypoxemia and hypercapnia may both be present with impaired alveolar ventilation, as would occur with respiratory compromise from a tension pneumothorax.

If tension pneumothorax is not treated quickly enough, the intrapleural pressure may rise to a level sufficient to cause life-threatening shock as a result of compression of the heart and great vessels. Once shock is present, it may be difficult to determine whether it has resulted from noncompressible hemorrhage or tension pneumothorax. NDC will be effective only in treating shock resulting from tension pneumothorax. If the tension is not relieved by NDC or other means, the hypoxemia and shock may result in a traumatic cardiac arrest.

One of the pioneers of needle decompression for tension pneumothorax was the late Dr Norman McSwain, who published a report on a new device developed for this purpose, the McSwain Dart, in 1982.[38] Treatment of tension pneumothorax with NDC is one of the relatively few interventions that has been shown to improve survival in victims of traumatic cardiac arrest.[39–43]

Tension Pneumothorax in Combat Casualties

In the Vietnam conflict, tension pneumothorax was reported to have been a leading cause of preventable death in combat casualties.[33,44] Needle decompression was not routinely used to treat tension pneumothorax during this conflict.[33]

Two factors have helped to reduce deaths from tension pneumothorax in combat casualties sustained during recent combat actions. One is the widespread use of personal protective equipment in the US military that includes protection for the anterior and posterior aspects of the thorax. Second, for more than two decades, combat medical personnel trained in TCCC have been taught to treat suspected tension pneumothorax aggressively with NDC. Largely as a result of these two innovations, the 2012 study by Eastridge et al. reported that tension pneumothorax was responsible for only 0.2% of deaths among US combat fatalities in the Afghanistan and Iraq conflicts, a decrease of greater than 90% in preventable deaths from this cause compared with the estimated 3% o 4% reported by McPherson in the Vietnam conflict.[1,33]

A Chronology of Suspected Tension Pneumothorax Management Recommendations in TCCC

The original TCCC Guidelines, published in 1996, recommended NDC (not a chest tube, as was being taught to Special Operations medics at the time) as the initial treatment for suspected tension pneumothorax.[45] There were no specific recommendations made at that time regarding the length of the catheter to be used for this purpose. The recommended catheter length for NDC before 2007 was 5 cm (2 in).[12]

US combat operations in Afghanistan began in October 2001 as a result of the al-Qaeda terrorist attacks on 9/11. It was reported in 2007 that in two US combat-related fatalities, 2-in needles failed to penetrate the chest wall and the casualties died with an unrelieved tension pneumothorax.[12] A subsequent series of virtual autopsy CT scans in 100 military fatalities done to examine chest wall thickness in US Servicemembers who had died found that the mean chest wall thickness was 5.36 cm.[12] The authors recommended use of a 3.25-in (8 cm) needle/catheter unit for NDC in order to achieve a 99% assurance of reaching the pleural space. As a result of this work and the two observed preventable deaths associated with using needles of insufficient length, both the US Army and the CoTCCC recommended that a 3.25-in needle be used for NDC instead of the previously used 2-in needle.[46,47] The need for an NDC device longer than 2 inches has also been reported in other studies.[48–50]

No published reports were identified in this review that described deaths in US combat forces due solely to tension pneumothorax as a result of failed NDC after the US military began aggressively treating suspected tension pneumothorax with 14-gauge, 3.25-in (8-cm) needles. The TCCC Guidelines prior to this change still recommended treatment of suspected tension pneumothorax with this device.[51,52]

Another change to the management of suspected tension pneumothorax in TCCC occurred in 2011. A polytrauma casualty presented on the Joint Trauma System (JTS) weekly trauma teleconference arrived at a medical treatment facility with no vital signs and CPR in progress. NDC had not been attempted during the prehospital phase of his care. He was successfully resuscitated with bilateral NDC in the Emergency Department. The TCCC Guidelines were subsequently changed to recommend bilateral NDC for casualties with torso trauma or polytrauma who develop a prehospital cardiopulmonary arrest.[4]

The most recent change to the TCCC Guidelines regarding needle decompression was made in 2012 and established the fourth or fifth intercostal space at the mid-axillary line as an alternate site to the previously recommended second intercostal space at the midclavicular line.[24] This recommendation for NDC sites was still in place at the time this change was undertaken.[3,52]

Since 2012, the TCCC guidelines have recommended the following management for suspected tension pneumothorax:

- "In a casualty with progressive respiratory distress and known or suspected torso trauma, consider a tension pneumothorax and decompress the chest on the side of the injury with a 14-gauge, 3.25-in needle/catheter unit inserted in the second intercostal space at the midclavicular line. Ensure that the needle entry into the chest is not medial to the nipple line and is not directed toward the heart. An acceptable alternate site is the fourth or fifth intercostal space at the anterior axillary line (AAL)."
- Additionally, NDC of both sides of the chest is recommended for any casualty who has a prehospital traumatic cardiac arrest.
- In the tactical evacuation (TACEVAC) phase of care, tube thoracostomy is recommended if that procedure is within the skill set of the individual providing care during evacuation.

This review considers the recommendations for treatment of a casualty with suspected pneumothorax in TCCC by discussing the following questions:
- When should a tension pneumothorax be suspected in a combat casualty?
- What should be the initial treatment of a suspected tension pneumothorax?
- How should the casualty be positioned for NDC?
- What device should be used for needle decompression?
- What site should be used for NDC?
- What is the best needle decompression technique?
- What findings indicate that NDC has been successful?
- What should be done if the initial NDC is not successful?
- What should be done if the initial NDC is successful but signs/symptoms subsequently recur?
- What should be done if the second NDC is also not successful?
- What site should be use for NDC?
- What is the prehospital treatment of refractory shock?

Discussion

When should a tension pneumothorax be suspected in a combat casualty?

TCCC has historically advocated for an aggressive approach to treating suspected tension pneumothorax, with the original TCCC report stating: "Progressive, severe respiratory distress on the battlefield resulting from unilateral penetrating or blunt chest trauma should be considered to represent a tension pneumothorax and that hemithorax decompressed with a 14 gauge catheter. The diagnosis in this setting should not rely on such typical clinical signs as breath sounds, tracheal shift, and hyperresonance on percussion because these signs may not always be present and, even if they are, they may be exceedingly difficult to appreciate on the battlefield . . . (NDC) is technically easy to perform, and may be lifesaving if the patient does in fact have a tension pneumothorax."[45]

There are many signs and symptoms reported in the literature as manifestations of a developing tension pneumothorax.[9,28,31,53–55] A partial list includes:
- Dyspnea—the subjective feeling of respiratory distress
- Increased depth and frequency of respirations
- Decreased hemoglobin oxygen saturation
- Decreased or absent breath sounds
- Hyperresonance to percussion
- Subcutaneous emphysema

- Tracheal deviation
- Jugular venous distention
- Shift of the mediastinal contents away from the side of the tension pneumothorax
- Tachycardia
- Shock
- Cardiac arrest

In reviewing these potential signs and symptoms, the CoTCCC sought to identify those that would be of greatest use to a combat medical provider in identifying a possible tension pneumothorax in the prehospital combat setting and indicating the need for NDC.

In order to make tension pneumothorax a significant consideration in evaluating a combat casualty, there must be an injury of sufficient severity and in the appropriate location to produce the one-way air leak that results in the accumulation of air under pressure in the pleural space. In a combat setting, that injury may be penetrating (GSW or fragment wound), blunt trauma (as with a combat-related motor vehicle crash or a fall), or, less commonly, pulmonary overpressure injury resulting from exposure to a blast wave.

Prehospital care guidelines in some civilian trauma systems are well-aligned with the TCCC approach of treating suspected tension pneumothorax on the basis of respiratory distress with or without accompanying hypotension if there is clinical evidence of blunt or penetrating chest trauma.[9,55–57] In one emergency medical services (EMS) system in Australia, the use of a more aggressive approach to suspected tension pneumothorax was documented to cause a decrease in unrecognized episodes of this disorder.[56] Respiratory distress/tachypnea and decreased or absent breath sounds on the affected side are a very common finding in tension pneumothorax.[6,28,31] Other signs such as jugular vein distention and tracheal shift were less useful in the prehospital environment.[6,55]

Other authors, however, place relatively more emphasis on the presence of shock as an indication for performing NDC for suspected tension pneumothorax in the presence of thoracic trauma.[6,53,54] This presents the question of whether or not one should wait for shock to develop in a casualty with thoracic trauma and respiratory distress before undertaking NDC, since NDC is not a completely benign procedure.

The Mayo Clinic study by Aho and colleagues noted respiratory improvement in 24 patients and hemodynamic improvement in only 4 patients after treatment for suspected tension pneumothorax, suggesting that prehospital personnel treated suspected tension pneumothorax largely on the basis of respiratory symptoms before the tension pneumothorax progressed and caused hemodynamic compromise and shock.[9] The study by Leigh-Smith states that respiratory distress is a universal finding in tension pneumothorax, while hypotension is present in only 25% of cases.[31] Roberts' review of case reports of tension pneumothorax noted that, in 86 spontaneously breathing patients, 45 had chest pain, 33 had dyspnea, 27 had shortness of breath, 36 had respiratory distress, and 40 had tachypnea, while only 16 had hypotension.[28]

Leigh-Smith and colleagues noted that, in animal models of tension pneumothorax: "The dominant physiological feature during decompensation was progressive respiratory failure

with death from respiratory, not cardiovascular, arrest."[31] Waydas states, "Experimental studies indicate that, in the awake patient, respiratory dysfunction and arrest due to hypoxia in the respiratory center precede the circulatory arrest, and that hypotension appears to be a late sign with circulatory arrest being the last occurrence in a series of events."[30]

The protocol for the Vanderbilt LifeFlight service calls for finger or tube thoracostomy if there is one 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 also calls for finger or tube thoracostomy to be performed on patients with multisystem injury or thoracoabdominal penetrating injury who are in trauma arrest."[53]

If tension pneumothorax is not relieved by NDC or tube thoracostomy early in its evolution, it may progress to life-threatening hypotension and traumatic cardiac arrest. There have been two recent deaths noted during the monthly JTS/AFMES Mortality Conferences in which postmortem CT scan demonstrated blood and air in the hemithorax with mediastinal shift and no definite evidence of attempted NDC. The amount of blood in the hemothoraces was not enough to have caused lethal hemorrhagic shock and the autopsies did not demonstrate any other lethal injuries (Lt Col Edward Mazuchowski, unpublished data). Additionally, a 2008 report from the Canadian military discussed opportunities for improvement in TCCC and reported that seven casualties had presented to medical treatment facilities with no vital signs but without having had prehospital NDC.[2] The lesson learned from both the US and the Canadian casualties described above is that the combat medical providers must be aware that tension pneumothorax is a reversible cause of traumatic cardiac arrest and that additional emphasis in TCCC training must be placed on this point. A similar issue has been reported in the civilian sector with a recent study noting that the most common error in the management of prehospital cardiac arrest in trauma patients is failure to treat for a possible tension pneumothorax; the incidence of tension pneumothorax in 144 traumatic cardiac arrest patients was found to be 9.7%.[58]

The TCCC Guidelines already recommend that a combat casualty with torso trauma or polytrauma who suffers a traumatic cardiac arrest before reaching a medical treatment facility should have bilateral NDC performed prior to discontinuing resuscitation efforts, but this clinical scenario is currently addressed only in the cardiopulmonary resuscitation section near the end of the Tactical Field Care (TFC) section of the Guidelines. Moving it up to the Respiration section to add extra emphasis on considering tension pneumothorax in a casualty with a traumatic cardiac arrest will help to increase awareness that bilateral NDC should be performed on combat casualties with thoracic trauma or polytrauma who suffer a traumatic cardiac arrest.

Recommendation for when to treat for suspected tension pneumothorax:

Suspect a tension pneumothorax and treat when a casualty has significant torso trauma or primary blast injury and one or more of the following:

– Severe or progressive respiratory distress
– Severe or progressive tachypnea
– Absent or markedly decreased breath sounds on one side of the chest
– Hemoglobin oxygen saturation less than 90% on pulse oximetry
– Shock
– Traumatic cardiac arrest without obviously fatal wounds

*Note: If not treated promptly, tension pneumothorax may progress from respiratory distress to shock and traumatic cardiac arrest.

What should be the initial treatment of a suspected tension pneumothorax?

If a chest seal is present
The TCCC Guidelines currently state that when a casualty who previously had an open pneumothorax—and who now has a chest seal in place—is suspected of having a tension pneumothorax, the first step is to "burp" the chest seal. That is—lift up the edge of the seal. This will allow the accumulated air in the pleural space that is responsible for the increased intrapleural pressure to escape.

Based on the work done by Kheirabadi and Kotora and their colleagues,[59,60] TCCC began to recommend the use of vented chest seals in 2013 to prevent the potential development of a tension pneumothorax when a chest seal is used to treat an open pneumothorax.[61] However, recent reports from the battlefield indicate that most of the chest seals now being used for US combat forces continue to be the nonvented type.[62] Even when vented chest seals are used, they may at times clog with blood and not function effectively to relieve intrapleural tension physiology.[63]

Recommendation:

– If the casualty has a chest seal in place, burp or remove the chest seal.

Pulse oximetry monitoring
The next step in the treatment sequence is to establish monitoring of hemoglobin oxygen saturation (Sp_{O_2}) by placing a pulse oximeter on a finger of the casualty. This will provide the treating combat medical provider with a baseline for Sp_{O_2}, which will be important both to determine whether hypoxia is present and to provide a baseline with which to judge the success or failure of further treatment.

Recommendation:

– Establish pulse oximetry monitoring.

How should the casualty be positioned for NDC?
Since tension pneumothorax may be accompanied by hemothorax, attempts at needle decompression may be unsuccessful if the tip of the needle rests in a blood-filled portion of the pleural space rather than an air space. This indicates that that optimal positioning of the patient may be important to ensuring successful needle decompression.

Although there is a theoretical advantage to performing NDC with the casualty in the sitting position, thereby allowing intrathoracic blood to move to a dependent position and air to rise to the most superior location in the pleural space, this maneuver may be difficult to accomplish in a severely injured casualty. Sitting upright may be ill-advised in some tactical situations; it is also contraindicated in casualties with suspected spinal cord injury. Finally, moving a casualty who is in shock into the sitting position may decrease blood flow to the brain and heart. Therefore, most casualties should be positioned supine (for anterior or lateral NDC) or in the recovery position (an alternative for lateral NDC) prior to decompression.

Recommendation:

– Place the casualty in the supine or recovery position unless he or she is conscious and needs to sit up and lean forward to help keep the airway clear as a result of maxillofacial trauma.

What device should be used for needle decompression?
The needle/catheter length recommended prior to 2008 was 2 in (4.5 to 5 cm).[12] Davis and colleagues reported a 60% success rate for NDC improving the signs and/or symptoms of tension pneumothorax when a 14- or 16-gauge needle was used for the procedure, but they do not specify what length needle was used. [57] Studies that have used CT exams of chest wall thickness have since found that 2-in needles are too short to reliably enter the pleural space.[12,17,49,64] Two-inch (or shorter) needles have also been associated with NDC failure in multiple reports[9,12,56,65–67] and should not be used. A failure rate of 80% for prehospital NDC was reported by Kaserer and colleagues. This study mentions that "many emergency medicine services in our vicinity are using standard venous catheters with a length of 33 mm to 50 mm for chest decompression."[65]

As noted previously, there were at least two US combat-related fatalities in the recent Middle Eastern conflicts in which 2-in needles failed to penetrate the chest wall and the casualties died with an unrelieved tension pneumothorax.[12] Both the US Army[47] and TCCC[52] modified their recommendations for NDC to call for a 3.25-in (8-cm) needle shortly after the findings of Harcke and his coauthors became known.

There have been no deaths from tension pneumothorax in US combat casualties attributed to failed needle decompression since the US military began aggressively treating suspected pneumothorax with 14-gauge, 3.25-in needles in accordance with TCCC Guidelines. The longer needle has also been recommended for use in the wilderness setting by Littlejohn.[68] The 2013 report by Harcke et al, described seven failures in 13 attempts at NDC when the anterior site for NDC was used.[18] A quote from that study notes: "While the literature has noted catheter length to be an important element in failure of needle decompression, it was not a factor in our cases. The change to 8 cm angiocatheters from 5 cm angiocatheters based on published chest wall thickness data appears to have eliminated this cause for an unsuccessful NDT." The study also does not state that any of the 16 combat fatalities included in the report died solely (or primarily) as a result of an unrelieved tension pneumothorax.

A Mayo Clinic retrospective study reviewed 91 NDC procedures performed on 70 patients. Patients who had NDC performed prior to March 2011 (when 5-cm needles were used for NDC) had a success rate of 41% compared with those who had NDC after March 2011 (when 8-cm NDC needles began to be used), who had a success rate of 83%. Of the 70 patients who underwent NDC procedures, 41 were prehospital and 29 were in-hospital. No complications were reported with either length needle. The site used for NDC in this study was the second ICS at the MCL.[9] Weichenthal and colleagues found a 63% rate of clinical improvement in trauma patients not in cardiac arrest who were treated with prehospital NDC using needles that were "at least 2 inches long."[39]

Despite the evidence noted above, the use of a 3.25-in needle has not been universally adopted. Several recent reports describe the use of 2-in (or shorter) needles.[65–67] Inaba et al reported that needle decompression at the second intercostal space in the midclavicular line using a 5-cm needle would be expected to fail in 42.5% of cases, based on CT examinations of 680 adult trauma patients.[69] The significant NDC failure rate with the shorter needles may have contributed to at least one report expressing skepticism about the use of NDC to treat suspected tension pneumothorax: "We found no evidence-based data to support the use of NT (needle thoracostomy) for tension pneumothorax."[66]

Other studies have proposed the use of needles of intermediate length between the 5-cm and 8-cm needles discussed above. A 2015 report from the UK reported a CT study of 63 combat casualties and prepared a predicted failure rate of various lengths of needle at several different sites on the chest wall. Based on this analysis they recommended that NDC needles not be longer than 6 cm for UK casualties.[70] A study from Singapore recommended a 7-cm catheter based on a CT review of chest wall thickness in trauma patients from that region.[48]

Considering 3.25 in to be the suitable length for needle used to perform NDC, attention is next directed to the recommendation for needle gauge. A 2009 Holcomb study found that a 14-gauge needle was just as effective as tube thoracostomy in treating tension pneumothorax in an animal model with an observation period of 4 hours,[11] but other animal models of tension pneumothorax have questioned whether a 14-gauge needle has the flow capacity needed to decompress a tension pneumothorax.[7,8,71,72] These seemingly contradictory findings may be due to variations in the animal models used, especially with respect to the amount of blood in the chest cavity, the severity of the initial pleural overpressure, and the amount of air introduced into the pleural space throughout the study to simulate an ongoing air leak. Causes of failure in the 14-gauge needle/catheter units used in these studies included migration of the catheter out of the thoracic cavity, kinking of the catheter after the needle was withdrawn, inadequate flow rate, catheter obstruction with tissue or clotted blood, and immersion of the needle and/or catheter tip in blood.[7,8,71,72] The 2017 Leatherman study recommended the use of a 10-gauge needle rather than the currently used 14-gauge needle to address concerns of treatment failure due to inadequate internal needle diameter. The authors of the present review, however, did not identify any clinical studies in which the safety and efficacy of 10-gauge versus 14-gauge needles as used for NDC were compared.

Despite concerns raised by the animal model studies noted above, clinical experience with 3.25-in, 14-gauge needles has been generally favorable.[18] As noted previously, the Mayo

Clinic found a success rate of 83% using the 14-gauge, 3.25-in needle recommended by TCCC.[9] The Chen report likewise reported no complications from NDC in 88 patients decompressed with a 14-gauge catheter.[6]

In addition to the 3.25-in, 10-gauge needle described here, there are commercially available 11-cm needles intended for use in needle decompression. These FDA-approved NDC devices include the Russell PneumoFix, a 12-gauge, 11-cm device, and the Enhanced Pneumothorax Needle, a 14-gauge, 8.6-cm device. Both devices use a Veress-type needle, which deploys a blunt-tipped cannula to cover the point of the needle after it has entered the pleural space. A PubMed search on these two devices did not reveal any published studies of their clinical use. No animal or clinical data was found in this review to document that an 11-cm needle length is needed (in preference to a 3.25-in needle) to reliably decompress a tension pneumothorax.

Other devices proposed for NDC based on animal models of tension pneumothorax include:
– the Vygon Catheter,[6,66]
– the ThoraQuik device,[73]
– a 5-mm laparoscopic trocar,[72]
– a modified Veress needle,[7,74] and
– the Reactor bladed trochar device.[75]

A concern with the use of larger and/or longer devices is that the rate of iatrogenic complications may increase. Potentially serious complications may result from NDC, including injury to intrathoracic organs such as the heart, pulmonary artery, subclavian artery, and lungs.[19,76,77] In addition, serious injuries can occur to structures outside the thoracic cavity such as the liver or spleen. There have been no published reports or JTS documentation of any major procedural complications from NDC in US combat casualties from the Afghanistan and Iraq conflicts, but this observation was made while the military was using 14-gauge needles, initially 5 cm in length and now 8 cm in length.

Recommendation:

– Decompress the chest on the side of the injury with a 14-gauge or a 10-gauge, 3.25-in needle/catheter unit.

What site should be used for NDC?
Complications from attempted NDC are uncommon but have been documented in published reports from the civilian sector and may include cardiac tamponade, life-threatening bleeding due to injuries to the pulmonary, internal mammary, subclavian, or intercostal arteries.[13,19,76,77] These complications have generally resulted from NDC attempts performed at the second ICS at the MCL, although this observation must be made with an understanding that the anterior site for NDC was the primary site recommended for that procedure until very recently; the lateral site was used only infrequently for this procedure in the past. The authors found no published prospective trials or retrospective case series designed to compare the complication rate from attempted NDC at the anterior site (second ICS at the MCL) versus the lateral site (fifth ICS at the AAL.) The 2015 Wernick report noted that: "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."[13]

Several studies have found that prehospital personnel frequently perform NDC at the anterior site more medially than recommended, putting the heart and great vessels at risk.[2,21] One small study of civilian paramedics found that 8 of 18 NDC attempts were performed medial to the MCL.[21] Tien and colleagues reported in 2008 that: "Seven NDs were performed on five soldiers for appropriate indications. All of these were Afghan army soldiers. All seven decompressions were performed at least 2 cm medial to the midclavicular line. No major complications resulting from the NDs were dentified."[2] The 2015 Inaba study found that Navy corpsmen using a cadaver model were able to locate the lateral NDC site correctly 78% of the time, but the anterior NDC site correctly only 18% of the time.[15] These studies have significant implications for training TCCC students in needle decompression, as discussed later in this report.

The lateral site for NDC has been proposed to be safer and/or associated with a higher success rate than the anterior site by multiple authors.[13,15,16,18–20,22,31,33,48,67,78] It is recommended as the primary site for NDC in the 10th edition of ATLS.[23] Other studies, however, still recommend or describe the use of the anterior site for NDC.[6,9,39,66,79]

The 2013 Harcke report found that less than half (6 of 13) of the NDC attempts at the anterior site could be seen to have actually entered the chest cavity in the 16 combat fatalities studied, whereas all (4 of 4) of the NDC attempts at the lateral site were found to have entered the chest cavity.[18] A 2011 study from the Canadian military found that a higher pressure was required to achieve free flow of air through catheters placed in the fifth ICS at the midaxillary line compared with those placed at the second ICS at the MCL. The authors suggested that catheters placed in the lateral site might kink more easily than those placed at the anterior site but declined to recommend one site over the other based on these findings. A recent study using a cadaver model found that the devices left in place after insertion at the lateral position for NDC were less likely to become dislodged than those left in place at the anterior site during combat casualty transport.[71]

A TCCC Working Group teleconference on this proposed change was held on 14 December 2017. Despite the published evidence cited above that might be interpreted as favoring the lateral site for NDC as the preferred site, there were several additional points made during the teleconference:

1. The anterior site has been widely used for NDC during combat operations in Iraq and Afghanistan and there have been no reports of major procedural complications in US casualties as a result;
2. Contingencies encountered on the battlefield may make it more advantageous to use either the anterior site or the lateral site, depending on the particular circumstances of a given casualty scenario, and medics should be able to use either site as required for a specific casualty;
3. No clinical studies were identified that have examined the relative safety and success rates of the lateral site as compared with the anterior site for NDC.

After discussion, most of the participants in the teleconference favored including both NDC sites without specifying a preferred site.[81] Further, the 2012 DHB report on needle decompression of suspected tension pneumothorax in TCCC stated that: "No definitive literature was found that establishes the superiority of the second intercostal space at the MCL over the fourth or fifth intercostal site at the AAL as the preferred site for needle decompression of a presumed tension pneumothorax.[24]

Recommendation:

– Either the fifth ICS in the anterior axillary line (AAL) or the second ICS in the MCL may be used for NDC. If the anterior (MCL) site is used, do not insert the needle medial to the nipple line.

Figures 1 and 2 show NDC being performed at the second ICS in the MCL in a cadaver model. Figures 3 and 4 show several instances of NDC intended to be at that location being performed too medially. Figures 5 and 6 show NDC being performed at the fifth ICS at the AAL in a cadaver model.

What is the best needle decompression technique?
As with most medical procedures, the technique used for NDC may greatly impact the success rate.

FIGURE 1 *NDC being performed at the second ICS in the MCL in a cadaver model.*

FIGURE 2 *NDC at the second ICS in the MCL with the needle removed and the catheter left in place in a cadaver model.*

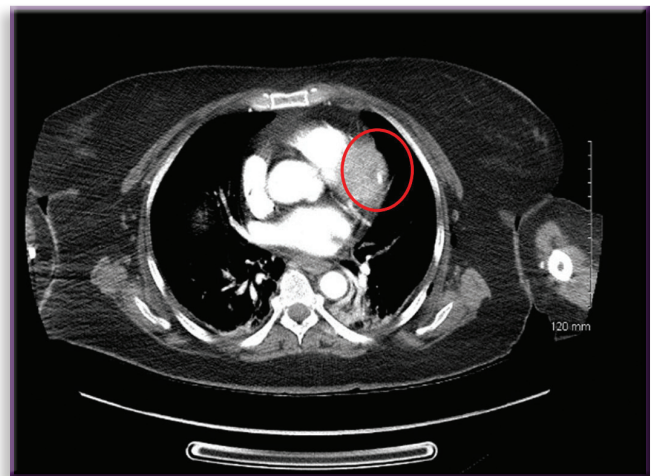**FIGURE 3** *Clinical photograph from a civilian trauma center showing multiple needle decompressions in both the anterior and the lateral locations. Note that two of the needles in the anterior site have been inserted at locations medial to the midclavicular line.*

FIGURE 4 *CT scan from a civilian trauma center showing a catheter that was used to perform needle decompression located in the myocardium.*

The first NDC technique recommendation is to insert the needle/catheter unit at a 90-degree angle (perpendicular) to the chest wall. An angulated insertion increases the distance the needle has to travel through tissue and decreases the likelihood of entering into the pleural space. If the angulation is cephalad, the likelihood of injuring intercostal vessels traveling in the neurovascular bundle at the inferior aspect of the rib above the intercostal space used may be increased.

Second, the entry point for NDC should be at the superior aspect of the lower rib at the insertion site used—again, in order to avoid the intercostal vessels located at the inferior aspect of the rib above.

FIGURE 5 *NDC being performed at the fifth ICS in the AAL in a cadaver model.*

Photograph courtesy of Maj Andrew Hall.

FIGURE 6 *NDC at the fifth ICS in the AAL with the needle removed and the catheter left in place in a cadaver model.*

Photograph courtesy of Maj Andrew Hall.

Third, the needle and catheter should be inserted together all the way to the hub. NDC attempts in which the catheter is advanced over a partially inserted needle have a high likelihood of not entering the pleural space and therefore not decompressing the tension pneumothorax. The 2013 Harcke report noted a number of cases in which the catheter was kinked within the muscles of the chest wall, without entering the pleural space.[18] One possible explanation for this finding is that the individual performing the NDC might have been hesitant to insert the needle to its full extent for fear of causing injury with the needle. Another possibility offered by the author of that study is that the findings might have resulted from a misapplied technique used in starting IVs, in which the needle is inserted only part way and then the catheter is inserted all the way as it is threaded into the vein (Dr Theodore Harcke, personal communication, 2017).

Fourth, the needle/catheter unit—prior to the needle being withdrawn—should be held in place for 5 to 10 seconds to allow time for full decompression of the pleural space to occur. This is already commonly done by combat medical personnel [MSG (Ret) Harold Montgomery, personal communication, 2017]. This maneuver helps to ensure that the pressurized air in the pleural cavity has adequate time to exit though the rigid structure of the needle, rather than having to pass through the flexible catheter alone, which may be more likely to become obstructed.

Fifth, after decompression, the needle should be removed in order to decrease the likelihood of iatrogenic injury. The catheter should be left in place so that it can provide ongoing decompression in the event that air is continuing to enter the pleural space from the injured lung. Leaving the catheter in place will also alert subsequent care providers that the casualty has been treated for a suspected tension pneumothorax. Despite this visible indication of a previous NDC, the procedure should still be noted on the TCCC Casualty Card (DD 1380.) Leaving the catheter in place is also common practice for military medics at present, but this step is mentioned as a specific step in the procedure to ensure that there is no misunderstanding. A caveat with respect to leaving the catheter in place is that it cannot be assumed that the catheter will reliably continue to decompress the pleural space—it may kink or become occluded with clotted blood.

Finally, if a casualty with thoracic trauma or polytrauma has sustained a traumatic cardiac arrest, both sides of the chest should be decompressed to ensure that the arrest is not due to an unrecognized tension pneumothorax on either side of the chest.

Recommendation:

– Use the technique described above to perform needle decompression.
– If a casualty has significant torso trauma or primary blast injury and is in traumatic cardiac arrest (no pulse, no respirations, no response to painful stimuli, no other signs of life), decompress both sides of the chest before discontinuing treatment.

What findings indicate that NDC has been successful?
Determining whether NDC has been successful at relieving a tension pneumothorax can be challenging in the prehospital setting.[83] One novel technique to verify entry into the pleural

space is the use of an NCD device with CO_2 detector. This technique has been shown to improve the accuracy of determining NDC success in an animal model. [83] This type of device is not, however, carried by most US combat medical personnel at the time of this writing. The Mayo clinic report on NDC defined success as ". . . documented improvement in respiratory status (increased oxygenation, decreased respiratory rate, or an improvement in ventilator requirements) or cardiovascular status (normalized heart rate and/or blood pressure or a return of pulses), or a documented "general improvement" in the patient's condition as per provider after NT was performed."[9]

As exemplified in the scenario presented at the start of this report and another recently published combat casualty care case report, it is not uncommon to see combat casualties undergo multiple NDC procedures during their prehospital care.[27] In some cases, this may occur because the symptoms of respiratory distress are caused by a condition other than a tension pneumothorax in which NDC does not produce improvement (eg, pulmonary contusion, hemothorax, or bronchial injury).[84] In other cases, however, the multiple attempts may have been undertaken because because the current TCCC Guidelines do not clearly state what constitutes success in NDC and do not provide recommendations about what to do if NDC is not successful in relieving the casualty's respiratory distress. In the casualty scenarios referenced above, the treating corpsman and medic observed improvement of their casualties' respiratory distress with each NDC procedure followed by subsequent deterioration. Such scenarios indicate that additional clarification is needed in the TCCC Guidelines, both about what constitutes success in NDC and how to proceed after the initial procedure.

What are the indications that NDC has been successful? A partial list of the potential clinical improvements includes:
– Subjective improvement in the casualty's respiratory distress or an observed decrease in his or her respiratory rate.
– Oxygenation improves, as indicated by hemoglobin oxygen saturation increasing to 90% or greater (note that this may take several minutes after the NDC to happen.)
– Air escaping from the overpressurized pleural space creates a hissing sound as air escapes from the chest during NDC. (This may be difficult to appreciate in high-noise environments and may not always be appreciable even in less noisy settings[83] [MSgt Shawn Anderson, personal communication] 2017.
– Hemodynamic improvement—a reduction in the signs of shock or a return of vital signs in a casualty with a traumatic cardiac arrest.

If the above clinical findings are noted, it is likely that the tension pneumothorax has been successfully treated, but, since the leak of air into the pleural space may persist, the tension pneumothorax may recur, so the casualty must be constantly re-assessed. If some respiratory distress persists but oxygenation, and heart rate are within the normal range and there are no signs of shock, it may not be necessary to repeat NDC.

If improvement in signs/symptoms is not seen after the NDC procedure, other causes must be considered. In penetrating thoracic trauma, respiratory distress and hemodynamic instability may also be caused by a hemothorax; in blunt trauma, pulmonary contusions, flail chest, or pain from rib fractures may also cause respiratory distress in the absence of a tension pneumothorax. The symptoms of respiratory distress caused by these conditions will not be relieved by NDC.

Recommendation:

A needle decompression procedure should be considered successful if:
– Respiratory distress improves, or
– There is an obvious hissing sound as air escapes from the chest when NDC is performed (this may be difficult to appreciate in high-noise environments), or
– Hemoglobin oxygen saturation increases to 90% or greater (note that this may take several minutes and may not happen at altitude), or
– A casualty with no vital signs has return of consciousness and/or radial pulse.

What should be done if the initial NDC is not successful?
The TCCC Guidelines do not at present include a sequence of steps to be undertaken if NDC fails to relieve the signs and symptoms of a suspected tension pneumothorax.[25]

As noted previously, there are some casualties in whom symptoms of respiratory distress, hypoxia, and/or shock are not relieved by NDC and multiple NDC attempts are undertaken by the treating combat medical provider—7 in one case[27] and 14 in the scenario presented at the beginning of this report.

Animal models have demonstrated that immersion of the tip of the needle in a hemothorax is one cause of NDC failure. If the initial NDC was performed on a casualty in the supine position, blood would be expected to have pooled at the posterior aspect of the chest, so a reasonable next step if the initial NDC was performed at the lateral site would be to perform the next attempt at the anterior site, where the tip of the needle would be less likely to be occluded by blood. Another cause of failed NDC is failure to penetrate the pleural space, possibly due to an unusually thick chest wall or a technical error in performing the NDC. Therefore, if the first decompression was attempted at the anterior site, the second attempt should be made at the lateral site.[34]

Recommendation:

If the initial NDC fails to improve the casualty's signs/symptoms from the suspected tension pneumothorax:
– Perform a second NDC—on the same side of the chest—at whichever of the two recommended sites was not previously used. Use a new needle/catheter unit for the second attempt.
– Consider—based on the mechanism of injury and physical findings—whether decompression of the opposite side of the chest may be needed.

What should be done if the initial NDC is successful, but signs/symptoms subsequently recur?
A positive response to the first NDC indicates that a tension pneumothorax was present on the side of the chest that was decompressed. After the initial successful NDC, following needle removal, the catheter may subsequently kink, become occluded, or migrate out of the pleural space, thereby allowing the re-accumulation of air in the pleural space with a subsequent recurrence of tension pneumothorax.

In this instance, the initial treatment should be repeated—on the same side of the chest—using a new needle/catheter unit.

In a review of the treatment rendered to casualties in the battle of Mogadishu 1993, Dr. Ken Zafren noted: "I did find research that showed that needle thoracostomies were likely to remain

patent. If a needle thoracostomy becomes obstructed, it is simpler to put in a second one rather than attempt a chest tube in the field. The 2nd needle thoracostomy should be just as effective as the first one. Continuous monitoring and reassessment of patients is necessary whether a needle or chest tube is in place."[85]

Recommendation:

If the initial NDC was successful, but symptoms later recur:
– Perform another NDC at the same site that was used previously. Use a new needle/catheter unit for the repeat NDC.
– Continue to re-assess!

What should be done if the second NDC is also not successful?
If two needle decompressions have been attempted and there has been no clinical improvement, the casualty's signs and symptoms may be caused by hemorrhagic shock or other conditions. The treating combat medical provider should therefore turn his or her attention to the next step in the sequence of care in the TCCC Guidelines—Circulation.

Recommendation:

If the second NDC is also not successful:
– Continue on to the Circulation section of the TCCC Guidelines.

What is the prehospital treatment of refractory shock?
Although untreated tension pneumothorax can potentially result in shock and death, a far more common cause of preventable death on the battlefield is shock that results from ongoing noncompressible hemorrhage. Shock from massive hemorrhage and shock from tension pneumothorax may be difficult to differentiate in the prehospital setting, since there may be considerable overlap in the physical findings. Since hemorrhagic shock is a far more common cause of preventable death in combat casualties than shock from tension pneumothorax,[1] and since NDC will treat only the latter condition, it is important to undertake hemorrhage control and resuscitation measures before returning to the possibility of a tension pneumothorax.

The combat medical provider should, therefore, proceed through the circulation section of the TCCC Guidelines and:
– Ensure that all external hemorrhage is controlled[3]
– Apply a pelvic binder if indicated[86]
– Assess for shock
– Start an IV or IO infusion if needed
– Administer TXA if hemorrhagic shock is present or likely[87]
– Perform fluid resuscitation with blood products if possible[25]

After all of the above interventions have been performed as indicated, if the shock state persists, the combat medical provider should consider untreated tension pneumothorax as a possible cause of refractory shock. Findings of thoracic trauma, persistent respiratory distress, absent breath sounds on one side of the chest, and hemoglobin oxygen saturation less than 90% would lend support to this diagnosis. In a casualty who has had at least two failed NDCs and who is suffering from refractory shock, more definitive measures need to be considered.[82]

Suspected tension pneumothorax should be treated in the prehospital setting with the least invasive intervention that will successfully resolve the casualty's shock and/or respiratory distress. This translates to needle decompression first, followed by either simple (finger) thoracostomy or chest tube placement, but only if shocks persists after two attempts at needle decompression and after having accomplished the other circulation measures listed above. In cases of pneumothorax or hemothorax, a simple (finger) thoracostomy will definitively ensure that the pleural cavity has been entered and decompressed, while tube thoracostomy will drain the chest and allow the lung to re-expand. Only those combat medical providers who have the appropriate skills, equipment, and authorization should perform these invasive procedures.

A description of finger thoracostomy (FT) was provided by High: "FT is performed the same way (as tube thoracostomy), 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."[53] No studies were identified, however, that document that finger thoracostomies will reliably remain patent and continue to prevent tension pneumothorax in the presence of an ongoing air leak from the lung injury without chest tube insertion.

Chest trauma that causes clinically significant pneumothorax or hemothorax will be treated with immediate tube thoracostomy at the casualty's first medical treatment facility, but inserting chest tubes in the prehospital combat setting has not been well-documented to improve outcomes. A 1985 Israeli study reported that only 8 of 16 prehospital chest tubes were inserted correctly and for the appropriate indications by physicians.[88] A more recent study from the Israeli Defense Force noted that 35 prehospital chest tubes had been placed after failed NDC, but the difference in outcomes associated with use of this more invasive intervention were not well described.[6] There are reports from the civilian sector that indicate that simple or tube thoracostomy can be safely and effectively accomplished by prehospital personnel and should be considered when NDC has failed.[31,34,53,57,68,89,90] The importance of experience in performing tube thoracostomy was highlighted by a 2017 study which noted that the complication rate for chest tube insertion was significantly greater (17%) when the procedure was performed by interns compared with 7% when the procedure was performed by residents.[91] Another study found that clinical improvement after tube thoracostomy was 61% compared with an improvement rate after NDC of 54%. The lack of a large increase in the clinical improvement rate in this study is an important point to bear in mind when considering more invasive interventions.[92] The authors of that study concluded: "From these data, we conclude that (needle decompression) is a relatively rapid intervention in the treatment of suspected (tension pneumothorax) in the prehospital setting; however, (tube thoracostomy) is an effective adjunct for definitive care without increasing morbidity or mortality. A better understanding of the physiology of intrapleural air masses is needed to determine the most effective decompression requirements prior to aeromedical transport."[92]

Consideration should also be given to decompressing the contralateral side of the chest if the injury pattern suggests that that is appropriate. Other interventions that may alleviate shortness of breath include ketamine administration for pain control[3] and supplemental oxygen.

Recommendation:

If a casualty in shock is not responding to fluid resuscitation, consider untreated tension pneumothorax as a possible cause

of refractory shock. Thoracic trauma, persistent respiratory distress, absent breath sounds, and hemoglobin oxygen saturation < 90% support this diagnosis. Treat as indicated with repeated NDC or finger thoracostomy/chest tube insertion at the fifth ICS in the AAL, according to the skills, experience, and authorizations of the treating combat medical provider. Note that if finger thoracostomy is used, it may not remain patent and finger decompression through the incision may have to be repeated. Consider decompressing the opposite side of the chest if indicated based on the mechanism of injury and physical findings.

Levels of Evidence for the Above Recommendations
The levels of evidence used by the American College of Cardiology and the American Heart Association were outlined by Tricoci in 2009:
– Level A: Evidence from multiple randomized trials or meta-analyses.
– Level B: Evidence from a single randomized trial or non-randomized studies.
– Level C: Expert opinion, case studies, or standards of care.[93]

Using the taxonomy above, the levels of evidence for the recommendations in this change are shown below.

When should a tension pneumothorax be suspected?
  Level C

How should the casualty be positioned for NDC?
  Level C

What device should be used for needle decompression?
  Level B

What site should be used for needle decompression?
  Level C

What technique should be used for needle decompression?
  Level C

What constitutes success in the initial treatment of tension pneumothorax?
  Level C

What should be done if the Initial needle decompression is not successful?
  Level C

What should be done if the initial needle decompression is successful but signs/symptoms subsequently recur?
  Level C

What should be done if the second NDC is also not successful?
  Level C

What should be the management for refractory shock due to tension pneumothorax?
  Level C

Training for Needle Decompression
Multiple reports have documented that NDC is often performed at incorrect locations, especially medial to the desired anterior (second ICS at the MCL) site.[2,18,21] Training for needle decompression in TCCC courses should include identification

of both the anterior and the lateral sites using the highest fidelity simulators available—fellow TCCC students. This training methodology mirrors that now used in TCCC courses to help students accurately identify the correct site for surgical cricothyroidotomy.[94] Demonstration of the procedure can then be performed on a manikin or a partial task trainer. The use of a cadaver-based training program to train this procedure has been found to result in improved performance over slide-based instruction alone.[95]

Proposed Change

Current Wording in the TCCC Guidelines

Tactical Field Care
5. Respiration/Breathing
   a. In a casualty with progressive respiratory distress and known or suspected torso trauma, consider a tension pneumothorax and decompress the chest on the side of the injury with a 14-gauge, 3.25-inch needle/catheter unit inserted in the second intercostal space at the midclavicular line. Ensure that the needle entry into the chest is not medial to the nipple line and is not directed towards the heart. An acceptable alternate site is the fourth or fifth intercostal space at the anterior axillary line (AAL).

Tactical Evacuation Care
4. Respiration/Breathing
   a. In a casualty with progressive respiratory distress and known or suspected torso trauma, consider a tension pneumothorax and decompress the chest on the side of the injury with a 14-gauge, 3.25 inch needle/catheter unit inserted in the second intercostal space at the midclavicular line. Ensure that the needle entry into the chest is not medial to the nipple line and is not directed towards the heart. An acceptable alternate site is the 4th or 5th intercostal space at the anterior axillary line (AAL).
   b. Consider chest tube insertion if no improvement and/or long transport is anticipated.

Proposed New Wording in the TCCC Guidelines

**New text in red

Tactical Field Care and Tactical Evacuation Care Respiration/Breathing
a. Assess for tension pneumothorax and treat as necessary

  1. Suspect a tension pneumothorax and treat when a casualty has significant torso trauma or primary blast injury and one or more of the following:
     – Severe or progressive respiratory distress
     – Severe or progressive tachypnea
     – Absent or markedly decreased breath sounds on one side of the chest
     – Hemoglobin oxygen saturation < 90% on pulse oximetry
     – Shock
     – Traumatic cardiac arrest without obviously fatal wounds
Note: If not treated promptly, tension pneumothorax may progress from respiratory distress to shock and traumatic cardiac arrest.

2. Initial treatment of suspected tension pneumothorax:
   – If the casualty has a chest seal in place, burp or remove the chest seal.
   – Establish pulse oximetry monitoring.
   – Place the casualty in the supine or recovery position unless he or she is conscious and needs to sit up to help keep the airway clear as a result of maxillofacial trauma.
   – Decompress the chest on the side of the injury with a 14-gauge or a 10-gauge, 3.25 inch needle/catheter unit.
   – If a casualty has significant torso trauma or primary blast injury and is in traumatic cardiac arrest (no pulse, no respirations, no response to painful stimuli, no other signs of life), decompress both sides of the chest before discontinuing treatment.

Notes:
*Either the fifth intercostal space (ICS) in the anterior axillary line (AAL) or the second ICS in the mid-clavicular line (MCL) may be used for needle decompression (NDC). If the anterior (MCL) site is used, do not insert the needle medial to the nipple line.
*The needle/catheter unit should be inserted at an angle perpendicular to the chest wall and just over the top of the lower rib at the insertion site. 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.
*After the NDC has been performed, remove the needle and leave the catheter in place.

3. The NDC should be considered successful if:
   – Respiratory distress improves, or
   – There is an obvious hissing sound as air escapes from the chest when NDC is performed (this may be difficult to appreciate in high-noise environments), or
   – Hemoglobin oxygen saturation increases to 90% or greater (note that this may take several minutes and may not happen at altitude), or
   – A casualty with no vital signs has return of consciousness and/or radial pulse.

4. If the initial NDC fails to improve the casualty's signs/symptoms from the suspected tension pneumothorax:
   – Perform a second NDC—on the same side of the chest—at whichever of the two recommended sites was not previously used. Use a new needle/catheter unit for the second attempt.
   – Consider—based on the mechanism of injury and physical findings—whether decompression of the opposite side of the chest may be needed.

5. If the initial NDC was successful, but symptoms later recur:
   – Perform another NDC at the same site that was used previously. Use a new needle/catheter unit for the repeat NDC.
   – Continue to re-assess!

6. If the second NDC is also not successful:
   – Continue on to the Circulation section of the TCCC Guidelines.

Add a section "e" to the Circulation Section of the TCCC Guidelines:

e. If a casualty in shock is not responding to fluid resuscitation, consider untreated tension pneumothorax as a possible cause of refractory shock. Thoracic trauma, persistent respiratory distress, absent breath sounds, and hemoglobin oxygen saturation < 90% support this diagnosis. Treat as indicated with repeated NDC or finger thoracostomy/chest tube insertion at the fifth ICS in the AAL, according to the skills, experience, and authorizations of the treating medical provider. Note that if finger thoracostomy is used, it may not remain patent and finger decompression through the incision may have to be repeated. Consider decompressing the opposite side of the chest if indicated based on the mechanism of injury and physical findings.

Figures 7, 8, and 9 are the TCCC Clinical Algorithms for the Respiration and Circulation sections of the TCCC Guidelines with the above change incorporated.

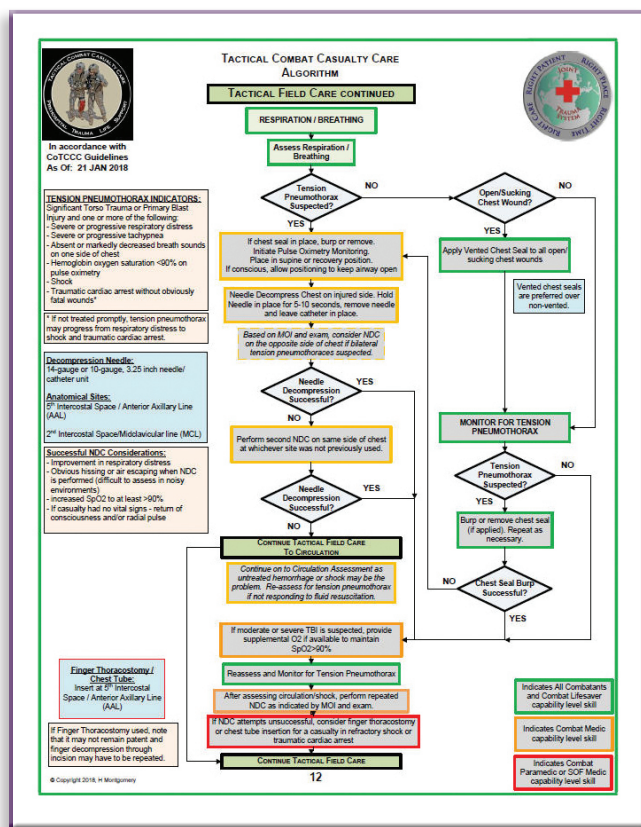FIGURE 7 TCCC Clinical Algorithm for the Respiration section of the TCCC Guidelines.

Figure courtesy of Mr Harold Montgomery.

Results of CoTCCC Vote:
This proposed change was approved by the required 2/3 or greater majority of the voting members of the CoTCCC.

Considerations for Further Research and Development

1. The DoD needs to field vented chest seals to deploying combat units to treat open pneumothorax, using the rapid-fielding model demonstrated by the 2004–2006 USSOCOM/USAISR TCCC Transition Initiative.[51,62,96]
2. Prospective, randomized clinical studies (or retrospective cohort studies) on the safety and efficacy of the anterior versus the lateral site for NDC should be conducted.

FIGURE 8 *First TCCC Clinical Algorithm for the Circulation section of the TCCC Guidelines.*
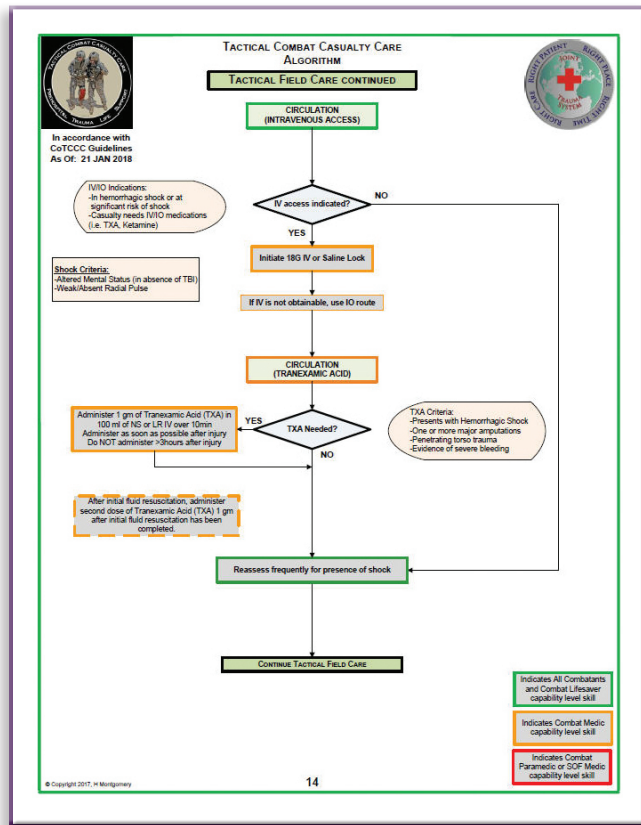

Figure courtesy of Mr Harold Montgomery.

FIGURE 9 *Second TCCC Clinical Algorithm for the Circulation section of the TCCC Guidelines.*
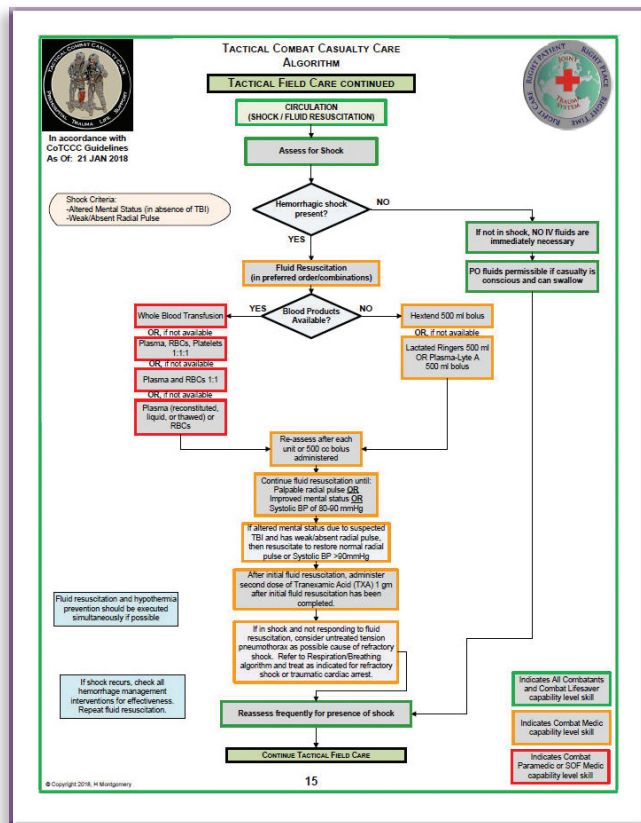

Figure courtesy of Mr Harold Montgomery.

3. Prospective, randomized clinical studies (or retrospective cohort studies) on the safety and efficacy of the various devices that are currently being used or have been proposed for NDC should be conducted:
   – Vygon Catheter[6,66]
   – ThoraQuik[73]
   – Russell PneumoFix
   – Enhanced Pneumothorax Needle
   – 5-mm laparoscopic trocar[72]
   – Modified Veres needle[7,74]
   – Reactor bladed trochar device[75]

4. Would emerging technologies that evaluate hemodynamic status such as the Compensatory Reserve monitor or computer-assisted monitoring technologies assist in better identifying tension physiology before the patient decompensates?

5. The monthly JTS/AFMES Preventable Death Review teleconferences should be continued and any fatalities in which the service member is found to have died of a tension pneumothorax should be addressed as Opportunities For Improvement.

6. Retrospective studies of NDC as performed on US military casualties to treat suspected tension pneumothorax should be performed using DoD Trauma Registry data. Areas of specific interest include:
   a. Identification of casualties meeting the criteria for pre-hospital NDC but who did not have the procedure performed should be identified and addressed as Opportunities for Improvement.
   b. The success rates of NDC as performed in the anterior site versus the lateral site should be compared.
   c. The success rates of NDC as performed with a 14-gauge, 3.25-in needle versus NDC as performed with a 10-gauge, 3.25-in needle should be compared.
   d. Casualties in whom NDC was performed should be examined for the indications and success of the procedures. In particular, the records of casualties with indications for NDC who have the procedure performed, but do not improve clinically as a result, should be reviewed to identify the incidence of other conditions that present similarly to tension pneumothorax.
   e. Complications resulting from tension pneumothorax should be identified and contributing factors such as site and needle used for the procedure should be noted.

7. As noted previously, the 2015 Inaba study found that Navy corpsmen using a cadaver model were able to locate the lateral NDC site correctly 78% of the time, but the anterior NDC site correctly only 18% of the time.[15] CT analysis from AFMES cases might be able to determine a way to help TCCC students more precisely locate the recommended sites for NDC using easily identified anatomic landmarks.

8. CT analysis might also be useful to define the relative hazard entailed in the two currently recommended sites for NDC. A virtual 8-cm catheter could be superimposed on the anatomy deep to the insertion sites, allowing the risk of vascular, solid organ, or cardiac injury to be more precisely defined.

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Acknowledgments

Disclaimers

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense. This recommendation is intended to be a guideline only and is not a substitute for clinical judgment.

Disclosures

The authors have no disclosures.

Release

This document was reviewed by the Director of the Joint Trauma System and by the Public Affairs Office and the Operational Security Office at the US Army Institute of Surgical Research. It is approved for unlimited public release.

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