

Management of Open Pneumothorax in Tactical Combat Casualty Care: TCCC Guidelines Change 13-02

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ABSTRACT

During the recent United States Central Command (USCENTCOM) and Joint Trauma System (JTS) assessment of prehospital trauma care in Afghanistan, the deployed director of the Joint Theater Trauma System (JTTS), CAPT Donald R. Bennett, questioned why TCCC recommends treating a nonlethal injury (open pneumothorax) with an intervention (a nonvented chest seal) that could produce a lethal condition (tension pneumothorax). New research from the U.S. Army Institute of Surgical Research (USAISR) has found that, in a model of open pneumothorax treated with a chest seal in which increments of air were added to the pleural space to simulate an air leak from an injured lung, use of a vented chest seal prevented the subsequent development of a tension pneumothorax, whereas use of a nonvented chest seal did not. The updated TCCC Guideline for the battlefield management of open pneumothorax is: “All open and/or sucking chest wounds should be treated by immediately applying a vented chest seal to cover the defect. If a vented chest seal is not available, use a non-vented chest seal. Monitor the casualty for the potential development of a subsequent tension pneumothorax. If the casualty develops increasing hypoxia, respiratory distress, or hypotension and a tension pneumothorax is suspected, treat by burping or removing the dressing or by needle decompression.” This recommendation was approved by the required two-thirds majority of the Committee on TCCC in June 2013.

KEYWORDS: *pneumothorax, chest seal, TCCC Guideline*

Proximate Cause for the Proposed Change

During the recent United States Central Command (USCENTCOM) and Joint Trauma System (JTS) assessment of prehospital trauma care in Afghanistan, the deployed director of the Joint Theater Trauma System (JTTS), CAPT Donald Bennett, questioned why TCCC

recommends treating a nonlethal injury (open pneumothorax) with an intervention (a nonvented chest seal) that could produce a lethal condition (tension pneumothorax).¹

New research from the U.S. Army Institute of Surgical Research (USAISR) has found that, in a model of open pneumothorax treated with a chest seal in which increments of air were added to the pleural space to simulate an air leak from an injured lung, use of a vented chest seal prevented the subsequent development of a tension pneumothorax, whereas use of a nonvented chest seal did not.²

Background

Current TCCC Guidelines call for an open pneumothorax (sucking chest wound) to be treated with an occlusive chest seal followed by careful monitoring of the casualty for the possible subsequent development of a tension pneumothorax. If a tension pneumothorax is suspected, the casualty should be managed by “burping” the occlusive dressing, thus allowing air to escape from the pleural cavity, or by needle decompression of the chest.³ There is no mention in the guidelines at present of whether the chest seal should or should not be vented.

During the recent USCENTCOM/JTS assessment of prehospital trauma care in Afghanistan, the Deployed Director of the Joint Theater Trauma System (JTTS), CAPT Don Bennett, recommended that this aspect of the TCCC recommendations be reviewed.¹ To quote from this report:

“Chest Seals (e.g. Asherman, Bolin, Halo, Hyfin, Russell, Sam) are variable in their adhesive abilities. Is the flutter valve beneficial? (Role I – USMC/USN) Is the chest seal itself beneficial? Or, does it convert a sucking chest wound into a life-threatening tension pneumothorax? “Why do we treat a non-lethal condition (open

pneumothorax) with an intervention that may result in a lethal condition (tension pneumothorax)?” (incoming JTTS deployed director)

There were no fatalities during OEF and OIF attributed to isolated open pneumothoraces.⁴ It is a matter of speculation as to whether discontinuing the current practice of treating open pneumothoraces with an occlusive chest seal might have caused fatalities.¹ There were 11 deaths from tension pneumothorax reported in the Eastridge study.⁴ Two of the 11 deaths from tension pneumothorax were associated with the use of a 2-inch needle for chest decompression and failure of the needle to enter the pleural space.⁵ It is not known whether any of these 11 deaths were associated with an open pneumothorax that was treated with an occlusive chest seal and converted to a tension pneumothorax.

Use of the shorter 2-inch needles was discontinued in the military after the findings noted by Dr. Harcke. The recommended needle for decompression of suspected pneumothorax at present is a 3.25-inch 14-gauge needle/catheter.^{3,6}

In a recent study of thoracic trauma from Iraq and Afghanistan, the authors noted that: “The mortality rate among all patients identified with thoracic trauma was 10.5%. Patients with flail chest, thoracic vascular injuries, hemothorax, or pulmonary lacerations had the highest mortality rates. Contusions, pneumothorax, flail chest, and chest wall trauma were associated with a lower mortality risk when controlling for covariates. Thoracic vascular injury was the diagnosis associated with the highest mortality risk.”⁷

Discussion Points

Historical Background

In World War I, “Primary closure of open pneumothorax, albeit without drainage, was a widely accepted practice.”⁸ The pathophysiology of open pneumothorax was described during World War II: “When a chest wall injury extends through the parietal pleura into the pleural cavity (normally only a potential space), two openings are present to admit air into the thorax. While on inspiration air enters the chest through both of these openings, it is only by way of the trachea and bronchi that air, with its necessary oxygen, can reach the pulmonary alveoli. It is evident that the percentage of air that reaches the lungs through the trachea is in inverse proportion to the size of the chest wall opening. When this differential is sufficiently great, not enough oxygen is available to sustain life even with the deepest inspiratory effort. The prompt application of a reasonably air-tight dressing to close the chest wall opening averts this disaster.”⁹

The emphasis in early reports describing the treatment of open pneumothorax was in closing the chest wall defect, without discussion of the potential development of a subsequent tension pneumothorax.⁹⁻¹⁴ This approach was echoed by Edgecomb in 1964: “Sucking Wounds of the Chest: If a wound of the chest wall communicates with the pleural cavity, there is usually an audible passage of air during both phases of respiration. When present, the opening should be occluded immediately with a sterile dressing and held in place either manually or with additional dressings until the patient is transported to the operating room where under endotracheal anesthesia and aseptic conditions, the wound can be closed properly, airtight and with proper drainage.”¹⁵

West noted a mortality of 33% in 30 casualties with sucking chest wounds. The deaths were predominantly due to hemorrhage or infection.¹⁶ The potential for the development of a secondary tension pneumothorax after treatment of an open pneumothorax was noted by Snyder in his report on wartime injuries of the chest.¹⁷

The danger of converting an open pneumothorax to a tension pneumothorax through the use of an occlusive dressing was demonstrated in a case report by Haynes. The author states: “Although the entities of tension pneumothorax and open pneumothorax have been adequately described individually, their association produced by emergency occlusive dressing in penetrating injuries of the chest has not been adequately stressed.”¹⁸ The possibility of a secondary tension pneumothorax after treatment of an open pneumothorax was noted by Sellors in his review of a textbook on thoracic injuries by Lawrence M. Shafts in 1957.¹⁴

In a canine model, animals with bilateral open chest wounds without positive pressure ventilation had either a 1-way valve dressing or petrolatum gauze applied to the wounds. The 1-way valve chest seal prevented “collapse” in 7 of 8 animals during a 15-minute observation period, whereas all 8 of the petrolatum gauze-treated animals suffered “collapse” during the observation period. Animals with both types of dressings were stable when they received positive-pressure ventilation.¹⁹

No case reports or case series were identified during the present review that reported fatalities resulting from an isolated open pneumothorax in the absence of significant injury to underlying thoracic structures or secondary infection. There was 1 case series found in which a sucking chest wound was associated with a fatal outcome, but the death was reported to have been caused by an infected hemothorax 3 weeks after the injury.²⁰

Three-Sided Chest Dressings

A 3-sided occlusive dressing was recommended by TCCC in the past for the initial management of open

pneumothorax. In a 2008 review of this guideline, it was noted that there was no evidence to show that improvised 3-sided dressings are reliably effective in preventing the conversion of an open pneumothorax to a tension pneumothorax.²¹ (CoTCCC Minutes July 2008) A 3-sided chest dressing is, however, still recommended by some authors.²²

As before, no evidence was found in the present review that improvised 3-sided dressings are reliably effective either in reversing the respiratory difficulty caused by an open pneumothorax or in preventing the conversion of an open pneumothorax to a tension pneumothorax.

At this point in time, there are no known commercially available chest seals designed to vent air from the pleural space by employing a single nonadherent side to the dressing. Commercially available vented chest seals incorporate a valve into their design to allow a 1-way flow of air out of the pleural space on exhalation but not back into the pleural space on inspiration.

Constructing a 3-sided chest seal takes more time for the medic than simply applying a commercially made chest seal. Variations in medic skill, available materials, and technique may introduce inconsistent clinical results when this option is used in battlefield conditions.

Recent Research Findings

A recent study at the USAISR found that treating open pneumothorax in an animal model with a chest seal did not cause the development of a tension pneumothorax when the chest seal incorporated a 1-way valve that allowed air to leave but not to enter the pleural space of the animals. Occlusive chest seals with no valve resulted in the development of a tension pneumothorax.² In this model, increments of 200ml of air were injected into the pleural cavity every 5 minutes until either tension pneumothorax developed or the volume of air injected equaled 100% of the animal's estimated total lung capacity (TLC).

The applicability of this model (the addition of 200ml of air to the pleural space every 5 minutes) to the pulmonary pathophysiology that might occur in a casualty as a result of an air leak from a lung injury underlying a chest wall defect is a point open for discussion.

A study performed at Madigan Army Medical Center to evaluate the adequacy of needle decompression in treating tension pneumothorax used a tension pneumothorax model in which CO₂ insufflation of the pleural space was performed in 5mmHg increments at a flow rate of 5L/min, with 2 minutes of stabilization between pressure increases.²³

In examining Figure 3 in the recent USAISR chest seal study, SpO₂ and Svo₂ values were still dropping when the

chest seals were applied 5 minutes after the open pneumothorax had been created in the animals.² It is uncertain whether they would have continued to decline or at what level they would have stabilized had the open pneumothorax been left untreated. In the words of the first author: “. . . the moment we opened the chest wound to the outside, the animal's breathing pattern changed drastically, breathing became more strenuous, the animal appeared to be uncomfortable and having more difficulties with each breath that was taken. What would have happened if we had left the chest hole open for a longer time, I can't say” (B.S. Kheirabadi, personal communication, 2013).

Even if open pneumothorax is not a lethal injury, the findings from the Kheirabadi study provide preliminary evidence that the hypoxia resulting from an untreated open pneumothorax could contribute to secondary brain injury in TBI casualties. If one is going to use a chest seal, there is no additional risk in using a vented one and there is potential benefit. No matter which type of chest seal is used, the casualty should be monitored closely for signs and symptoms of a subsequent tension pneumothorax.

In contrast, there is now animal model evidence that use of an unvented chest seal in the presence of an ongoing intrathoracic air leak from an injured lung causes accumulation of air in the pleural space and the possible development of a tension pneumothorax. The Naval Operational Medical Lessons Learned Center TCCC Equipment Evaluation Report from November 2011 noted that a majority of the chest seals used in theater were vented.²⁴

Chest Seals

The Asherman chest seal has been recommended as a faster and more reliable approach to managing open pneumothorax than a 3-sided dressing,^{22,25} with the 3-sided dressing recommended as a back-up if an Asherman seal was not available.²² The Asherman chest seal was later noted to have problems with adherence to the chest.³ It is currently the lowest-rated chest seal in the NMLLC survey on chest seals.²⁴ In a comparison of two vented chest seals, the Bolin and the Asherman seals were found to be equivalent in preventing the development of a tension pneumothorax. The Bolin chest seal was found to have better adherence to the chest wall in blood soiled conditions.²⁶

The Hyfin and the Bolin were the 2 highest-rated vented chest seals in the Navy Medical Lessons Learned Center TCCC Equipment Survey.²⁷ The Bolin was the vented chest seal used in the recent ISR study on open pneumothorax.² In a study designed to quantitatively assess the adherence of commercially available chest seals (Bolin,

Halo, Sherman, H&H, Hyfin, Russell, SAM-valved, Sentinel) in a simulated chest-wound model, volunteers were sprayed with a mixture of construction sand and canned evaporated/condensed milk, simulating the blood and sand/dust typically found in combat wounds. They then had chest seals applied to the simulated wound and adherence quantification performed. The authors concluded that “. . . the SAM-valved and Bolin chest seals were most effective in retaining optimal adherence throughout a simulated combat casualty encounter.”²⁸

In a swine model of open pneumothorax, the investigators created the injury and then applied a HyFin, a SAM, or a Sentinel vented chest seal to the wound to see whether these devices would prevent the development of a tension pneumothorax when air was injected into the pleural space. The authors concluded that the “HyFin, SAM, and Sentinel vented chest seals are equally effective in evacuating blood and air in a communicating pneumothorax model. All three prevented tension pneumothorax formation after penetrating thoracic trauma.”²⁹

Conclusions

There are now data from an animal model of open pneumothorax and ongoing intrathoracic air leak treated with both vented and nonvented chest seals that document that a vented chest seal prevents the subsequent development of a tension pneumothorax and that a nonvented chest seal does not.² In observance of *primum non nocere* (first, do no harm), it is best to err on the side of safety in treating open pneumothorax, and the animal data noted here suggest that vented chest seals may confer a safety advantage over unvented chest seals in treating open pneumothorax in the presence of an ongoing air leak from an injured lung.

This statement is especially true on the battlefield, where a single multitasked medic in a mass casualty situation may be distracted by other casualties and fail to notice a developing tension pneumothorax in a casualty who has had his or her open pneumothorax treated with an unvented occlusive dressing.

Proposed Change to the TCCC Guidelines

Current wording

Tactical Field Care

3. Breathing

b. All open and/or sucking chest wounds should be treated by immediately applying an occlusive material to cover the defect and securing it in place. Monitor the casualty for the potential development of a subsequent tension pneumothorax.

Tactical Evacuation Care

2. Breathing

d. All open and/or sucking chest wounds should be treated by immediately applying an occlusive material to cover the defect and securing it in place. Monitor the casualty for the potential development of a subsequent tension pneumothorax.

Proposed wording

Tactical Field Care (New text in red)

3. Breathing

b. All open and/or sucking chest wounds should be treated by immediately applying a **vented chest seal** to cover the defect. **If a vented chest seal is not available, use a non-vented chest seal.** Monitor the casualty for the potential development of a subsequent tension pneumothorax. **If the casualty develops increasing hypoxia, respiratory distress, or hypotension and a tension pneumothorax is suspected, treat by burping or removing the dressing or by needle decompression.**

Tactical Evacuation Care

2. Breathing

d. All open and/or sucking chest wounds should be treated by immediately applying a **vented chest seal** to cover the defect. **If a vented chest seal is not available, use a non-vented chest seal.** Monitor the casualty for the potential development of a subsequent tension pneumothorax. **If the casualty develops increasing hypoxia, respiratory distress, or hypotension and a tension pneumothorax is suspected, treat by burping or removing the dressing or by needle decompression.**

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

Level of evidence: Level C (ACC/AHA – Tricoci 2009³⁰)

Considerations for Further Research

- 1) Animal studies are needed to determine the incidence of mortality from an untreated open pneumothorax as an isolated injury.
- 2) Data from the DoD Trauma Registry should be evaluated to determine what can be learned from the registry with regard to:
 - The number of open pneumothorax injuries sustained
 - Methods of treatment, including types of commercial chest seals used
 - Outcomes of treatment
 - Presence or absence of events in which an unvented chest seal caused an open pneumothorax to convert to a tension pneumothorax.

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Disclosures

The authors have nothing to disclose.

Disclaimers

The recommendation contained herein is the current position of the DoD Committee on Tactical Combat Casualty Care. It is intended to be a guideline only and is not a substitute for clinical judgment.

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

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Additional Readings

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