The Journal of Emergency Medicine, Vol. 45, No. 5, pp. 686–694, 2013
Published by Elsevier Inc.
Printed in the USA
0736-4679/$ - see front matter

http://dx.doi.org/10.1016/j.jemermed.2013.05.011

Selected Topics: Prehospital Care

VENTED CHEST SEALS FOR PREVENTION OF TENSION PNEUMOTHORAX IN A COMMUNICATING PNEUMOTHORAX

Joseph G. Kotora Jr., LCDR, MC, USN, DO, Jose Henao, CDR, MC, USN, MD, Lanny F. Littlejohn, CDR, MC, USN, MD, and Sara Kircher, BS

Department of Emergency Medicine, Naval Medical Center Portsmouth, Portsmouth, Virginia
Reprint Address: Joseph G. Kotora Jr., CDR, MC, USN, DO, One Harmony Lane, Hackettstown, NJ 07840

☐ **Abstract—Background: Tension pneumothorax accounts for 3%–4% of combat casualties and 10% of civilian chest trauma. Air entering a wound via a communicating pneumothorax rather than by the trachea can result in respiratory arrest and death. In such cases, the Committee on Tactical Combat Casualty Care advocates the use of unvented chest seals to prevent respiratory compromise. Objective: A comparison of three commercially available vented chest seals was undertaken to evaluate the efficacy of tension pneumothorax prevention after seal application. Methods: A surgical thoracostomy was created and sealed by placing a shortened 10-mL syringe barrel (with plunger in place) into the wound. Tension pneumothorax was achieved via air introduction through a Cordis to a maximum volume of 50 mL/kg. A 20% drop in mean arterial pressure or a 20% increase in heart rate confirmed hemodynamic compromise. After evacuation, one of three vented chest seals (HyFin®, n = 8; Sentinel®, n = 8, SAM®, n = 8) was applied. Air was injected to a maximum of 50 mL/kg twice, followed by a 10% autologous blood infusion, and finally, a third 50 mL/kg air bolus. Survivors completed all three interventions, and a 15-min recovery period. Results: The introduction of 29.0 (±11.5) mL/kg of air resulted in tension physiology. All three seals effectively evacuated air and blood. Hemodynamic compromise failed to develop with a chest seal in place. Conclusions: 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. Published by Elsevier Inc.**

☐ **Keywords—chest seals; pneumothorax; thoracic trauma; combat; tactical**

INTRODUCTION

Despite the advances in personal protective equipment, penetrating chest trauma remains a formidable cause of injury in tactical medicine. The Joint Theater Trauma Registry, a collective database of all coalition-force casualties from the conflicts in Iraq and Afghanistan, implicates thoracic trauma as the cause of lethal injury in 5%–7% of all patients (1,2). The leading mechanisms of lethal injury among deployed service personnel are improvised explosive devises (IEDs) and gunshot wounds from small arms fire (2). Although the blast waves from IEDs can cause significant lung injury, high-velocity fragments

Grant obtained through the Bureau of Medicine and Surgery, United States Navy.

The views expressed in this article are those of the author(s) and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, or the United States Government.

Three authors are military service members. This work was prepared as part of their official duties. Title 17 U.S.C. 105 provides that "Copyright protection under this title is not available for any work of the United States Government." Title 17 U.S.C. 101 defines a United States Government work as a work prepared by a military service member or employee of the United States Government as part of that person's official duties.

RECEIVED: 26 June 2012; FINAL SUBMISSION RECEIVED: 29 December 2012;
ACCEPTED: 1 May 2013

can also cause devastating injury through secondary and tertiary blast injuries. This is the predominant wounding mechanism when IEDs cause chest trauma (1). Civilian tactical operators are at risk for similar kinetic mechanisms of injury.

Open pneumothorax and tension pneumothorax are two of the most frequently fatal wounds seen among combat casualties. In addition, these wounds are readily treatable in the prehospital phase and are therefore two of the leading causes of preventable combat death. In one study examining the prevalence of tension pneumothorax in injured military personnel, radiographic evidence of tension pneumothorax was discovered in 198 of 978 casualties (3). Although tension pneumothorax is a clinical diagnosis that should be treated before obtaining any radiographic study, the study by McPherson et al. underscores the relatively high incidence of missed tension pneumothorax in combat casualties (3). If the size of the chest wall defect is equal to or greater than two thirds the diameter of the trachea, air will preferentially enter the chest wall during inspiration, rather than the trachea, resulting in respiratory failure and eventual cardiopulmonary arrest (4). Classical teaching regarding the management of an open pneumothorax involves placement of an occlusive dressing over the wound. This procedure has been endorsed by both civilian and military medical organizations (5). The current recommendation by the Committee on Tactical Combat Casualty Care (CoTCCC) endorses this mechanism in their most recent guidelines (6).

Although there are no published data comparing the vented chest seals to three-sided occlusive dressings, some have argued against the use of three-sided occlusive dressings. The Royal College of Surgeons endorses the use of chest seals in open pneumothoraces, and agree that a three-sided occlusive dressing is "often ineffective" (7). Equally important, this intervention often requires frequent "burping" by prehospital medical personnel to relieve air accumulated and avoid development of a tension pneumothorax (5). When prehospital care providers in austere and technically difficult environments under low-light conditions are faced with multiple casualties with penetrating chest trauma, this can become an arduous task with a high likelihood of increased morbidity and mortality.

In light of these concerns, vented chest seals were developed. These seals are designed to prevent inward airflow through the chest wound, while simultaneously allowing the evacuation of air from the chest through the valve during normal spontaneous respiration.

Commercially available chest seals used to treat open pneumothoraces can fail due to poor adhesion to human skin (8). Adhesion can be further compromised by blood, sweat, dirt, and debris. Arnaud et al. studied this phenomenon in 2008 by comparing the Asherman and Bolin chest seals for development of tension physiology after application in an open pneumothorax model. The results of their study did not reveal any evidence of tension pneumothorax after application of a vented chest seal (8). However, since this study, several chest seals have been developed and marketed to the United States (US) military and civilian tactical law enforcement agencies. To date, there has been no published data comparing the efficacy of commercially available vented chest seals against one another.

The purpose of this study was to test three commercially available vented chest seals (HyFin®, SAM®, and Sentinel®) currently used by US military units for the treatment of open pneumothorax in the tactical environment. Each vented seal was assessed for its ability to prevent accumulation of air with resultant development of tension physiology after application. In addition, each seal was evaluated for its ability to adequately vent blood in the face of a hemopneumothorax. In addition to having a venting mechanism, each chest seal had to meet the criteria established by the CoTCCC. These criteria are presented in Table 1.

The study end point was development of tension pneumothorax after application of the chest seal, defined by any of the following possible entities: a drop in the mean arterial pressure (MAP), a rise in heart rate, both a decrease in MAP and a rise in the heart rate, or death. Bedside ultrasound was utilized to assess the presence or absence of a pneumothorax, both before and after

Table 1. Committee on Tactical Combat Casualty Care Required Criteria for Chest Seals (6)

Required Criteria
Approved by the US Food and Drug Administration
Sterile
Long shelf life
Adherence required in the presence of blood, sweat, sand, and hair
Must conform to Military Standard 8.10 G regarding storage
Low allergic potential
Self adherent
6–8 inches in dimension
Oval shaped
Creation of an occlusive seal
Ventable through lifting of an occlusive flap on the seal with adequate resealing after lifting
Puncture-resistant packaging
Minimum weight and cube
Maintenance of integrity when folded
Lightweight and rugged
Inexpensive
Favorable clinical data when tested under battlefield conditions
Easy application under battlefield conditions
Built in tabs to facilitate removal
High rate of user acceptance
Configuration for use in low-light conditions

US = United States.