



“Decompression of tension pneumothorax in a trauma patient –first use of a novel decompression colorimetric capnography device in human patient”

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Abstract

Tension pneumothorax is a common cause of mortality in trauma. Tension pneumothorax is the confinement of respired gases within the pleural cavity at increasing pressure resulting in hemodynamic collapse. Decompression is crucial in management. Emergency needle thoracostomy is a life-saving maneuver that allows atmospheric pressure equilibration and partial restoration of cardiac filling. Needle decompressions are usually performed under noisy, tense, and stressful circumstances, and objective assessment of success is difficult in the field. A device which is simple that objectively informs operators of successful decompression would be clinically useful. In previous work, we have demonstrated end-expiratory gas and gaseous composition of tension pneumothorax are similar due to increased carbon dioxide partial pressure relative to atmospheric gas composition. Therefore, a simple solution to objective needle decompression may be colorimetric capnography.

We report a case of 58-year-old male treated by EMS following a motorcycle accident with left-sided chest pain, hypoxia, hypotension, and clinical findings of tension pneumothorax. Needle decompression with colorimetric capnography using the device indicated decompression of his tension pneumothorax, with appropriate temporizing success.

Keywords Needle thoracostomy · Colorimetric capnography · Tension pneumothorax · Advanced trauma life support (ATLS) · Needle decompression · Emergency medical systems/service (EMS)

Introduction

Trauma is a major cause of morbidity and mortality in the United States for both the military and civilians [1–5]. A major cause of mortality in those with penetrating or blunt chest trauma is tension pneumothorax. Advanced Trauma Life Support (ATLS) is the standard operating procedure for the resuscitation of trauma worldwide [6]. During ATLS resuscitation, life-threatening injuries are prioritized, such as those which interfere with gas exchange and cardiac function, including tension pneumothorax. The standard of care during pre-hospital and hospital resuscitation of the trauma patient with tension pneumothorax is needle decompression through needle thoracostomy. Unfortunately, the standard by which this is judged effective is “an audible gush of air” and improvement in vital signs.

A tension pneumothorax is the confinement of respired gases within the pleural cavity at pressures higher than atmosphere that is caused by an air leak within the respiratory system resulting in hemodynamic collapse. Current

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needle thoracostomy technology relies on surface anatomy for placement, and proper insertion can be confounded due to chest wall thickness, anterior or lateral placement, and inability to reliably hear an “audible gush of air.” Visual recognition of respired gases during needle thoracostomy would be a simpler method for detecting needle thoracostomy efficacy. Because the gaseous composition of the tension pneumothorax is similar to that of end-respiratory gas, notably an increased partial pressure of carbon dioxide when compared to the normal atmosphere, colorimetric capnography is an ideal confirmatory test [7]. Previously, we demonstrated that using colorimetric capnography in a model of tension pneumothorax may have advantages for providing timely operator feedback that tension physiology was present and that decompression was effective [7]. In this work, we aim to demonstrate that the use of colorimetric capnography is safe and may be effective in removing operator subjectivity in the field during transport for decompression of tension pneumothorax. This represents the first case report of using this device in human patient.

Methods

We employed a commercial-grade manufactured device which uses a Luer lock and one-way valve which can be affixed to any needle or angiocatheter for tension decompression (Fig. 1). The device samples in-line air flowing out from the patient through the one-way valve to the sampling chamber with capnography paper then flowing freely to the atmosphere. This colorimetric capnography paper is purple/blue in ambient air (0.04% CO₂ by volume), but when

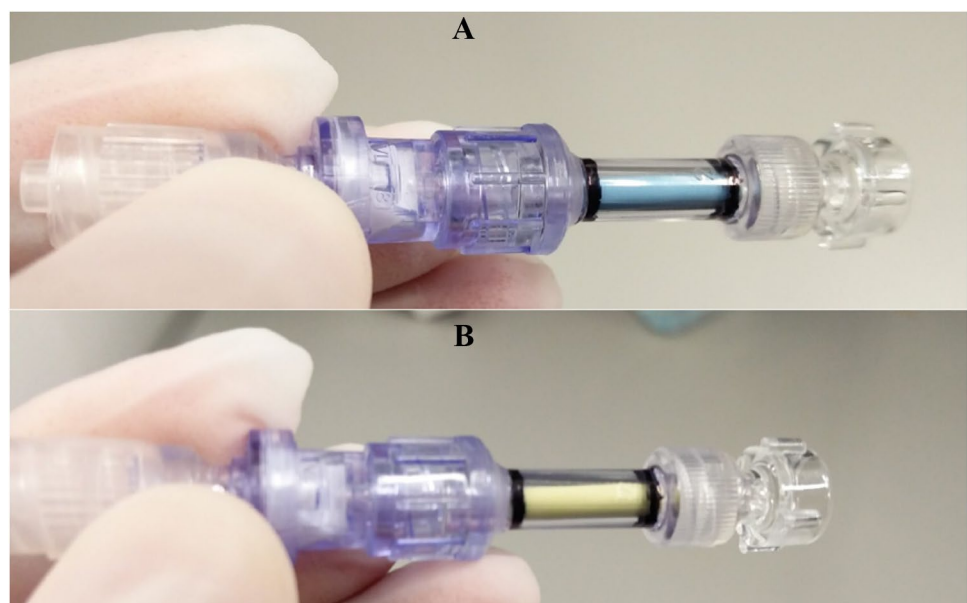
exposed to expired air (5% CO₂ by volume), it changes to bright yellow within 3–5 s.

Case report

A 58-year-old male sustained injuries during a motorcycle crash at highway speed and was transferred to the local hospital where he was found to have decreased breath sounds on the left side. He was hemodynamically normal. He was subsequently airlifted to our trauma facility. During air transportation, he developed progressive hypotension to 55 mm Hg systolic, respiratory distress and oxygen saturation of 88% while spontaneously breathing on oxygen support. Needle decompression was performed on the left hemithorax at the second intercostal space, mid-clavicular line. The colorimetric capnography was affixed to the end of the needle thoracostomy, and after approximately 20 s, there was obvious color change from purple/blue to yellow after approximately 5 breaths (approximately 10–20 s). The needle was left in place and the color change remained persistent. After needle decompression was performed, saturations improved to 98% after approximately 30 s. The flight crew administered 1 unit of cold whole blood with minimal improvement.

Upon arrival to our trauma center, standard ATLS resuscitation was performed. During the resuscitation, a left chest tube was placed which drained air and approximately 200 cc of blood. Focused Assessment with Sonography in Trauma demonstrated fluid within the abdominal cavity prompting emergent laparotomy. At exploration, the left diaphragm was noted to be bulging suggesting retained blood or air within the left hemithorax; the chest tube output was also noted to be increased. A left thoracotomy was performed,

Fig. 1 We used a custom needle based device. The device has a in line gas chamber for a colorimetric capnography indicator to be exposed to escaping gas. The capnography indication paper was placed in this chamber, distal to a one-way valve that prevents air ingress during decompression but allows free gas egress from the needle. This colorimetric capnography paper is purple/blue in ambient air (0.04% CO₂ by volume), but when exposed to expired air (5% CO₂ by volume) it changes to bright yellow within 3–5 s



with over a liter of clotted and fresh blood expressed. There was ongoing hemorrhage from an unidentified source in the left chest prompting aortic cross clamping and packing of the left chest cavity. During these maneuvers, the patient became asystolic. Despite open internal cardiac massage and internal defibrillation as well as ongoing resuscitation with blood products, the patient never had return of spontaneous circulation. After 15 min, the patient was pronounced deceased. The cause of death was deemed to be exsanguination from traumatic transection of descending thoracic aorta at autopsy.

Discussion

Timely and effective needle decompression of tension pneumothorax saves lives. However, the standard of care, based on ATLS guidelines, of “an audible gush of air” [6] is challenging in an austere environment, during transportation, and even during trauma resuscitations. These environmental factors clearly impair an operator’s ability to know if the needle thoracostomy was effective. This novel device depends on colorimetric capnography to help the healthcare providers to confirm the placement of the needle thoracostomy in an accurate and prompt matter. Capnography is common for endotracheal intubation and user-friendly as well as familiar to most operators. The ability to make a definitive and objective assessment of the success of needle decompression is crucial. Application of the device in this case was able to provide near real-time, visual feedback for detection of CO₂ suggesting that tension pneumothorax was present.

When exposed to expired air (5% CO₂ by volume), the colorimetric capnography paper changes color from purple/blue to yellow in 3–5 s. However, in some cases, color change may be delayed to 10–20 s, suggesting probable mixing of expired CO₂ with dead space air. Once the paper color changed to yellow, patient vital signs improved subsequently, indicating successful needle placement.

In addition, there is no free gas in the virtual space between the parietal and visceral pleura under normal conditions. As a result of the pressure gradient, any communication between the pleural space and the enclosing structures (bronchi, alveoli, extra thoracic communication through the chest wall) instantly causes gases to enter the pleural space leading to a pneumothorax [8]. The rate of gas absorbed from the pleural space relies upon on four variables: (1) the pressure gradients for the gases in the pleural place in relation to the venous blood; (2) the extent area of contact between the pleural gas and pleura; (3) the permeability of

the pleural surface (for example a fibrotic pleura absorbs less than a normal pleura); (4) the diffusion properties of the gases given in the pleural space [7].

Furthermore, during discussions afterwards, it was determined that the device was simple in application, color change was rapidly apparent, and took minimal time to affix it to the needle thoracostomy. A thoracostomy needle with an integrated capnography chamber would obviate the need to affix the device to the needle thoracostomy but would require further specialized devices and may limit generalizability. This device, in either form, carries the potential to increase the accuracy of placement in tension pneumothorax. In our previous work using an animal model, needle capnography decompressions showed 100% success rate in comparison to 60% in standard of care needle decompression [7].

This device requires further clinical trials which we are undertaking, but may have efficacy for field confirmation in both civilian and military settings if commercial opportunities for manufacturing develop and regulatory scrutiny are met. Improving care for those who are injured with tension pneumothorax is critical. There is a need to remove operator subjectivity and change care to a quantifiable metric for needle decompression.

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