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ORIGINAL RESEARCH

A MATCHED COHORT STUDY OF OPEN THORACOSTOMIES PERFORMED BY GROUND MEDICS

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ABSTRACT

***Background*:** Tension pneumothorax resulting from chest trauma is a rapidly fatal condition that requires prompt treatment. Prehospital open thoracostomy (POT) is a potentially lifesaving intervention that can be performed in the field to treat tension pneumothorax. However, the results from POT performed by ground EMS providers have not been well-studied. The objective of this study was to compare outcomes for patients with chest trauma who underwent POT performed by ground EMS providers with a matched cohort who did not undergo this procedure in the field.

***Methods*:** A retrospective chart review of consecutive adult patients presenting to a Level I trauma center with chest trauma were analyzed from 2017-2020. Outcomes were compared to a patient cohort who did not undergo POT matched by severity of injury and prehospital CPR.

***Results*:** A total of 14 POT patients were identified. Majority of POT were bilateral (n=11/14, 78.6%) and all of these patients (n=14/14) had prehospital cardiac arrest. Return of spontaneous circulation was obtained in 2 patients with penetrating injuries (14.3%). There was no difference in total and scene EMS time compared to the matched cohort without POT (p>0.05).

Conclusions: This study demonstrated that open thoracostomies could be performed by ground EMS units without increasing prehospital time for severely injured trauma patients and greater achievement of ROSC. Larger, prospective, multi-institutional analyses are needed to further evaluate outcomes.

INTRODUCTION

Tension pneumothorax (tPTX) is a rapidly progressive condition resulting in significant mortality from obstructive shock and cardiac arrest if left untreated. Identification and treatment of tPTX in the prehospital setting can be a life-saving measure for patients prior to definitive management. Performance of nee-

dle thoracostomy (NT) in the prehospital setting by medics is one approach to relieve tPTX. However, the efficacy of this procedure has recently been brought into question (Robitaille-Fortin, 2021; Axtman, 2019; Martin, 2012; Kaserer, 2017). The ability of NT to deliver successful and reliable decompression of the thoracic cavity in patients with suspected tPTX remains unclear (Robitaille-Fortin, 2021). Previous studies have shown a relatively high failure rate of NT to relieve tPTX (Axtman, 2019; Martin, 2012; Kaserer, 2017). NT has also been shown to have lower rate of successful intra-thoracic placement due to variety of reasons which include catheter kinking, misplacement, and blockage of the catheter during placement.

In 2017, the Tactical Combat Casualty Care (TCCC) guidelines recommended an aggressive approach to treat tPTX based upon mechanism of injury and respiratory distress (Butler, 2018). Open thoracostomy (OT) is identified as an additional treatment option for suspected tension pneumothorax after two unsuccessful NT attempts. The medical provider must have the necessary training and the patient have clinical signs of shock. Despite the emergence of OT in the prehospital setting, few previous studies have evaluated its outcomes (Chesters, 2016; Dickson, 2018; Massarutti, 2016; Hannon, 2020; High, 2016; Jodie, 2017; Mistry, 2009; Jodie, 2017). Two recent systematic reviews found varying success with OT and several reported complications (Robitaille-Fortin, 2021; Sharrock, 2021). The objective of this study was to measure clinical outcomes for patients with chest trauma who underwent prehospital open thoracostomy (POT) by ground EMS units and also to determine if POT increased prehospital EMS time. We hypothesized that patients with chest trauma and signs of tPTX could efficiently undergo POT in the field by prehospital ground EMS providers.

METHODS

A retrospective chart review of consecutive adult patients with chest trauma who presented to University Hospital in San Antonio from January 1, 2017- May 31, 2020 was performed. Subjects under 18 years of age, prisoners, and pregnant women were excluded. Institutional Review Board approval from obtained from the University of Texas Health Science Center at San Antonio. A Health Insurance Portability and Accountability Act (HIPAA) waiver of informed consent was obtained.

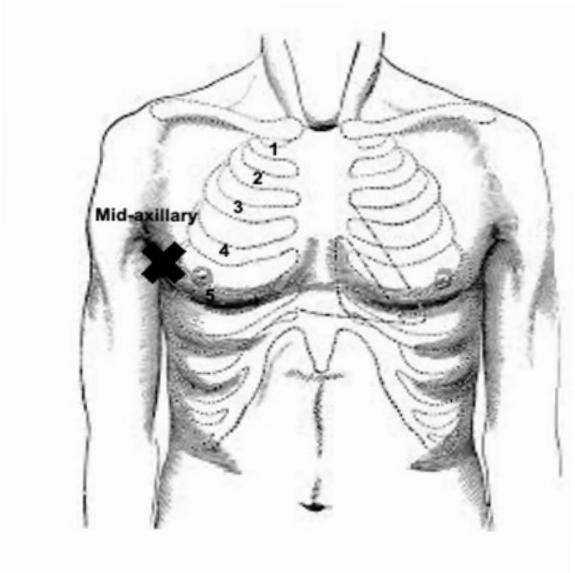

Figure 1 – Anatomic landmarks for performance of prehospital open thoracostomy using finger or Kelly clamp.

Data were also obtained from San Antonio Fire Department (SAFD) to further identify patients who underwent open thoracostomies in the field. San Antonio Fire Department responds to all major trauma incidences with a dual paramedic staffed mobile intensive care unit, and a four personnel fire department first responder unit, and an EMS medical supervisor. All paramedics receive annual continuing education in performance of POT (San Antonio Fire Department,

2022). Training includes both didactic and psychomotor skills in a cadaveric based training. Entry into the pleural cavity is performed with either the medic's gloved finger or a Kelly clamp at the 5th intercostal space, between the anterior axillary and midaxillary line as demonstrated in Figure 1. Prehospital triggers for open thoracostomy are shown in Figure 2. SAFD is the only prehospital agency in San Antonio currently performing POT.

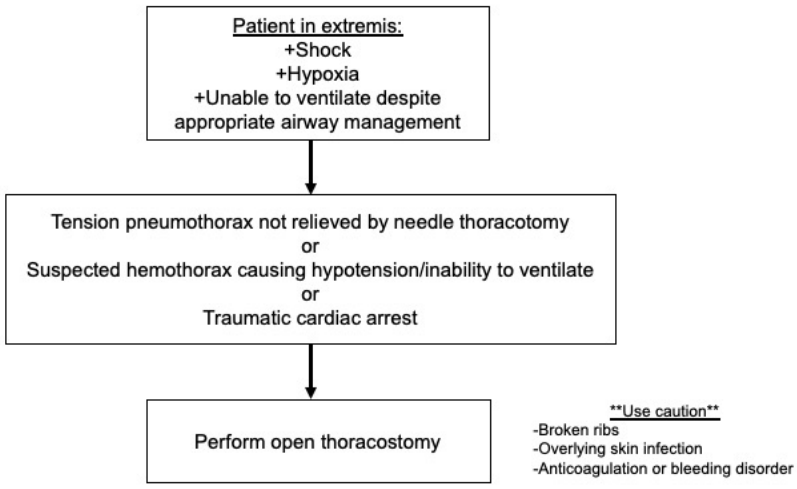

Figure 2 – Criteria for open thoracostomy in the prehospital setting.

Patient demographics (age, co-morbid conditions, gender, race, mechanism of injury), EMS scene time, total EMS time (defined as the sum of dispatch to scene, scene time, and scene to hospital transport time), prehospital interventions (needle thoracostomies, open thoracostomies, CPR, intubation), procedures in the ED (chest tube, ED thoracotomy, intubation, CPR), operative intervention, return of spontaneous circulation (ROSC), and mortality were recorded. Outcomes from patients who had open thoracostomies in the field were compared to a matched cohort who did not have these interventions in the field. A historical cohort of patients with chest trauma using ICD 9/ICD 10 codes from the Trauma Registry was used to create a matched group. The two cohorts were matched 1:1 based upon age, gender, mechanism of injury, injury severity score (ISS), and abbreviated injury scale (AIS) of the chest.

Statistical analysis was performed with continuous variables compared using the Mann Whitney U test. Fisher's exact test were used to compare categorical variables. Mean and standard error of mean (SEM) or median and interquartile range (IQR) were calculated where appropriate. Categorical data were calculated as percentages. Prehospital vital signs (i.e., heart rate, systolic blood pressure, respiratory rate) and Glasgow Coma Scores (GCS) were reported as median values with ranges. Data were analyzed using GraphPad software (version 5, La Jolla, CA) and IBM SPSS (version 27, Armonk, NY). Statistical significance was defined as $p \leq 0.05$.

RESULTS

Patient Demographics and Injury Mechanism

A total of 1281 patients with chest trauma were reviewed and 14 (1.1%) prehospital open thoracostomies were performed by ground EMS. For patients with POT, the average age was 38.4 +/- 5.7 years and 71.4% were men (n=10/14). The average BMI was 29.3 +/- 2.5. Penetrating mechanism was the cause of injury in 42.9% (n=6/14) with average ISS 33.5 +/- 5.7 and average chest AIS 3.7 +/- 0.4.

Patients were compared to a matched cohort of similar injury patterns in patients who sustained chest trauma and did not have POT. Subjects were well matched in terms of age, gender, BMI, ISS, AIS chest, and incidence of penetrating mechanism of chest trauma (p>0.05). These results are summarized in Table 1.

Baseline Demographics	POT (n = 14)	No POT (n = 12)	p value
Age, yrs (SEM)	38.4 (5.7)	45.3 (18.7)	0.32
Male gender, n (%)	10 (71.4)	10 (83.3)	0.65
BMI, avg (SEM)	29.3 (2.5)	28.7 (6.7)	0.71
Injury severity score, avg (SEM)	33.5 (5.7)	39.1 (4.8)	0.37
Abbreviated injury scale, chest, avg (SEM)	3.7 (0.4)	3.5 (1.1)	0.71
Penetrating mechanism, n (%)	6 (42.9)	3 (25.0)	0.43

Table 1 – Baseline patient demographics and mechanism of injury for trauma patients who underwent a prehospital open thoracostomy (POT) compared to a matched cohort of patients who did not undergo POT.

Prehospital Characteristics

Average EMS scene time in the POT cohort was 12.7 +/- 1.1 minutes and 15.8 +/- 3.0 minutes in the non-POT group, (p = 0.86). The total time from alert of emergency services to arrival to the ED was 37.6 +/- 4.9 minutes in the OT group and 36.9 +/- 4.2 minutes in the non-OT (p = 0.86). In the POT group, 85.7% of patients (n=12/14) were intubated prehospital, while 83.3% (n=10/12) from the non-OT group were intubated prehospital (p = 1.0). There was a significant difference in the number of patients receiving prehospital blood between the OT (n = 8/14, 57.1%) and non-OT (n =2/12, 16.7%) groups (p=0.05). All patients in the POT group (n=14/14, 100%) and non-POT group (12/12, 100%, p =1.0) had traumatic prehospital cardiac arrest. Table 2.

Scene Characteristics	POT (n = 14)	No POT (n = 12)	p value
EMS Time scene, min, avg (SEM)	12.7 (1.1)	15.8 (3.0)	0.86
Total EMS time, min, avg (SEM)	37.6 (4.9)	36.9 (4.2)	0.86
Intubated in the field, n (%)	12 (85.7)	10 (83.3)	1.0
Prehospital cardiac arrest, n (%)	14 (100)	12 (100)	1.0
Prehospital blood, n (%)	8 (57.1)	2 (16.7)	*0.05*
Open Thoracostomies			
Needle thoracostomy, n (%)	6 (42.9)	5 (41.7)	1.0
Bilateral needle thoracostomy, n (%)	5 (35.7)	2 (16.7)	0.39
Intrathoracic NT, n (%)	2 (33.3)	2 (16.7)	1.0
In-Hospital Care			
ED Glasgow coma scale, median (IQR)	3 (3-3)	3 (3-3)	0.53
Resuscitative thoracotomy, n (%)	6 (42.9)	2 (16.7)	0.22
Chest tube, n (%)	7 (50.0)	12 (100)	*0.006*
Operative Thoracotomy, n (%)	1 (7.1)	8 (66.7)	*0.003*
Return of spontaneous circulation, n (%)	2 (14.3)	10 (83.3)	*0.001*
Mortality, n (%)	12 (85.7)	12 (100)	0.48

Table 2 – Prehospital information and in-hospital care for trauma patients who underwent a prehospital open thoracostomy (POT) compared to a matched cohort of patients who did not undergo POT.

Prehospital Open Thoracostomies

Among patients in the POT group, 78.6% (n=11/14) had bilateral open thoracostomies performed in the prehospital setting. No injuries to providers were reported by EMS agencies who performed POT in these patients.

Prehospital Open Thoracostomies and Needle Decompression

A total of 11 patients in both groups had prehospital NT with 42.9% (n=6/14) in the POT group undergoing NT prior to OT. Compared to the performance of NT in the non-POT group (n=5/12, 41.7%), this was not found to be statistically different (p=1.0). There was also no difference in the rate of bilateral NT between the two groups (p=0.39). Due to hemodynamic instability, chest radiograph and computed tomography of the chest were not performed in all patients. Imaging was performed in 42.9% (n = 6/14) in POT group and 50.0% (n=6/12) in non-POT group. There were 33.3% of patients (n=2/6) in the POT and non-POT groups (n=2/6) who had radiographically confirmed successful intrathoracic placement of needle thoracostomy, which was not statistically difference between the two groups (p=1.0).

In-Hospital Procedures, ROSC, and Mortality

Median GCS score on ED arrival was the same for the POT and non-POT groups (p=0.53). In the POT group, 50.0% of patients (n=7/14) underwent tube thoracostomy placement through a different chest access site after arrival to the emergency department compared to 100.0% (n=12/12) patients in the non-OT group (p=0.006). Resuscitative thoracotomy was performed in 42.9% (n=6/14) in the POT group and 13.3% (n=2/12) in the non-OT group (p=0.08). Only one patient (7.1%) of the POT group went on to have a formal operative thoracotomy compared to 10 patients (66.7%) in the non-POT group (p=0.003).

The POT group had lower overall mortality compared to the non-POT group but this was not statistically significant (n=12/14, 85.7% vs n=12/12, 100.0%, p=0.17). In the POT group, there were two patients who survived pre-hospital cardiac arrest to obtain ROSC and ultimately survived to hospital discharge (n=2/14, 14.3%). While the non-POT group had a higher incidence of ROSC, there were no survivors to discharge (n=0/12) in the non-POT group (p=0.48).

DISCUSSION

In this study, there was no difference in both EMS scene time or total time to definitive care. This observation suggests that concerns over delay in presentation to definitive care to perform finger thoracostomy were not supported. Similarly, a study by Fok and colleagues investigating factors that prolong scene EMS time found that POT did not significantly increase scene time to the hospital (Fok, 2019).

Due to the significant mortality associated with tPTX, the need for rapid and effective treatment is needed. OT is emerging as an alternative treatment in the prehospital

setting. Based on the data presented in this study and previous literature supporting the use of OT in the prehospital setting, OT has been demonstrated as a safe treatment option for suspected tPTX (Chesters, 2016; Dickson, 2018; Massarutti, 2016; Hannon, 2020; High, 2016). This study presents one of the first initial analyses of this procedure performed by ground EMS providers.

All patients in this study who underwent POT were in prehospital cardiac arrest with a survival rate of 14.3% with two patients obtaining ROSC. This observation suggests appropriate selection of patients by ground EMS medics. Prior studies have shown that tPTX-induced cardiac arrest swine models had a high rate of failure to restore perfusion when only NT was performed, which suggests that particularly in this subgroup of individuals in traumatic arrest that OT is a suitable alternative or adjunct to NT in attempts to restore perfusion. In addition, several studies have questioned whether NT is being performed correctly by EMS in the prehospital setting. POT may provide better outcomes for successful decompression of the chest (Aylwin, 2008; Shapey, 2012; Kaserer, 2017; Weichenthal, 2018).

There was no difference in rates of resuscitative thoracotomies or tube thoracostomy placement among the two groups upon arrival to the hospital. This outcome is expected given both the severity and mechanism of the traumatic injuries sustained by the two groups as well as the high mortality rate. Additionally, OT and NT are not intended to be performed as definitive procedures for chest decompression, thus a majority of patients who had OT or NT would likely have additional interventions upon arrival to the hospital performed by physicians such as resuscitative thoracotomies, tube thoracostomy, and formal operative thoracotomy. The rate of operative thoracotomy was significantly higher in the non-OT group. Based on the high rate of mortality in the OT group, these patients likely expired prior to operative intervention.

Questions regarding the safety of this procedure have raised some concerns for performing OT in the prehospital setting to both providers and patients. In this study, there were no reported injuries to the prehospital providers after performing OT, suggesting these procedures are safe to perform for providers when properly trained. There were no reported complications directly related to prehospital performance of OT. Although, given the various other interventions (e.g., tube thoracostomy, resuscitative thoracotomy, central venous catheterization) that are performed in patients with similar injury severity and patterns, concluding an association of complications directly related to the finger thoracostomy procedure would be challenging. This analysis is limited due to the relatively high mortality rate of subjects in this investigation. One study by Massarutti et al. showed that in 55 consecutive severely injured patients with suspected PTX who underwent OT, there were no cases of major bleeding, lung laceration, or pleural infection (Massarutti, 2006). Other studies have had comparable outcomes in complications related to OT including empyema rate and major bleeding which suggests that there are minimal complications associated with performing OT.

This study has several notable limitations which merit further discussion. First, the retrospective nature of this study may have introduced a selection bias. The study is also limited by a relatively small sample size and the evaluation of a single center. This

study did not evaluate competency in prehospital providers in performance of POT. However, a recent study by Fairley and colleagues of SAFD determined that almost 80% of medics correctly identified the anatomic locations for NT and POT (Fairley, 2021).

Prehospital cardiac arrest was the main indication for performance of POT. As more experience is gained with this procedure, other criteria need to be evaluated as indications such as the presence of tension pneumothorax since these patients could also possibly benefit from POT. Additional prospective, multi-institutional studies would need to be performed to evaluate competency measures, and to assess whether it has any measurable impact on traumatic outcomes.

CONCLUSIONS

This study demonstrated that FT can be performed by ground EMS units without increasing prehospital time or added morbidity for severely injured trauma patients. The results from this study add to the growing body of literature to support the prehospital utilization of finger thoracostomies. Continued education of EMS providers on this procedure and proper patient selection is essential to the wider adoption of this practice. Larger, prospective, multi-institutional analyses are needed to further evaluate outcomes in order to definitively provide evidence to the superiority of FT over NT.

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