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RESEARCH REPORT

# COMPARISON OF OUT OF HOSPITAL FINGER AND NEEDLE THORACOSTOMY PERFORMED BY GROUND EMERGENCY MEDICAL SERVICES

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## ABSTRACT

*Introduction*: Tension pneumothorax related to chest trauma is a rapidly lethal condition that requires immediate treatment, often prior to arrival at definitive care. Recent concerns regarding the safety and efficacy of needle thoracostomy (NT) have led to alternatives. Finger thoracostomy (FT) is a potential life-saving treatment performed by prehospital providers as an alternative to NT. We hypothesize that FT has improved rates of prehospital thoracic decompression and is a safe alternative to NT.

*Materials and Methods*: Retrospective cohort study of consecutive adult trauma patients presenting to a Level 1 trauma center who sustained chest trauma. A matched cohort of patients with an initial prehospital treatment with FT was compared to patients who underwent prehospital NT for thoracic decompression. Wilcoxon Rank Sum Test and Chi-Squared Analyses were performed for comparison of prehospital and in-hospital outcome variables.

*Results*: 34 patients were compared, of which 15 underwent prehospital FT and 19 underwent prehospital NT. Groups were well matched in terms of demographics and injury characteristics. No difference in transport times were observed. All 15 patients in the FT group sustained cardiac arrest prior to arrival with 20% achieving return of spontaneous circulation (ROSC), while 6/19 NT patients arrived in cardiac arrest, with 66.7% achieving ROSC ($p=0.04$). The rate of successful intrathoracic decompression was higher in the FT group (93.3% vs 47.4%, $p<0.001$). The NT group had a higher rate of chest tube placement ($p=0.005$). In-hospital mortality was not different between the two groups ($p=0.213$).

*Conclusions*: FT is a viable alternative to NT for emergent thoracic decompression. The higher success rate of intrathoracic decompression supports the use of FT as a primary or second line treatment to NT for prehospital tension pneumothorax, although future studies are needed to establish superiority and further evaluate mortality and in-hospital outcomes.

## INTRODUCTION

Tension pneumothorax (PTX) secondary to chest trauma is a potentially life-threatening injury pattern that has significant mortality rate if untreated, but also able to be intervened upon if recognized early. Intervention by out of hospital providers may be critical in reducing mortality from tension PTX prior to definitive management (e.g., tube thoracostomy). Performance of needle thoracostomy (NT) is the traditional intervention for rapid treatment of tension physiology, but recent literature has called into question both the efficacy of thoracic decompression (Robitaille-Fortin, 2021; Axtman, 2019; Martin, 2012; Kaserer, 2017) and safety due to iatrogenic injuries sustained from placement of needle thoracostomy (e.g., cardiac, great vessel, lung).

The most recent Tactical Combat Casualty Care guidelines recommend early treatment of suspected tension PTX based on congruent mechanism of injury (e.g., chest trauma) and respiratory compromise (Butler, 2018). Finger Thoracostomy (FT) has been proposed after two unsuccessful attempts with NT. Several studies have raised concerns of adequate intrathoracic placement of needle decompression devices due to variations in technique, anatomical location of needle placement, and relative variability in chest wall thickness at different anatomical locations (Martin, 2012; Kaserer, 2017; Laan, 2016). Although FT (also referred to as open thoracostomy) has emerged as an alternative to needle thoracostomy, there is relatively little literature comparing finger and needle thoracostomy directly (Chesters,2016; Dickson, 2018; Massarutti, 2006; Hannon, 2020). Concerns regarding the safety of NT in the emergent settings have called it into question due to the risk of significant intrathoracic injury (Wernick, 2015), as well as finding an appropriate size device for adequate chest wall penetration that is capable of decompressing the thoracic cavity (Zengerink, 2008).

We hypothesize that out of hospital FT will be associated with increased rates of successful intrathoracic decompression, when performed by appropriately trained out of hospital emergency providers (defined as paramedics and emergency medical technicians who have had prior training by supervisor of physician in proper technique), without a delay in transport to definitive care.

## MATERIALS AND METHODS

After approval by the Institutional Review Board for the University of Texas Health Science Center at San Antonio, data were queried from an institutional trauma registry of all patients who sustained chest trauma treated with prehospital thoracic decompression. The manuscript has been prepared in accordance with the Equator Network STROBE guidelines (www.equator-network.org). Subjects reviewed consisted of consecutive adult trauma patients presenting to a Level 1 trauma center who sustained chest trauma between January 1, 2017 and December 31, 2020. Patients were eliminated from consideration if it was deemed that they did not sustain chest trauma or did not have prehospital performance of thoracic decompression. Patients were also eliminated from consideration if they were transferred from another facility and/or had definitive thoracic decompression prior to arrival (e.g., tube thoracostomy). Training for the performance of NT were in accordance with national guidelines and the certification through the Advanced Trauma Life Support course. Training in the performance of FT was carried out by individual emergency transport companies for their providers. Protocols for performance of

NT and FT are based on recommendations from the regional emergency response agency, South Texas Regional Advisory Council (STRAC). Out of hospital providers who were compared in this study were all capable of performing FT and NT and were previously trained. EMS agencies that were not trained in either procedure or both were not included in the analysis.

Records regarding performance of NT or FT were obtained from emergency medical service agencies who report all out of hospital data to a prospectively collected trauma registry. Anatomical location of where NT was performed was at the discretion of out of hospital provider (4th/5th intercostal space at the anterior axillary line or 2nd intercostal space at midaxillary line). In-hospital data were collected from the institutional trauma registry and chart review process. Inclusion criteria for this study required subject to be over the age of 18, who sustained chest trauma and were transported directly to the Level I trauma center who had out of hospital concern for tension PTX and required NT and/or FT. Regional EMS providers serviced a large urban city as well as an catchment radius that included several rural counties, but all overseen by STRAC which provided standardized guidelines for performance of NT and FT which were in place and not modified over the duration of this study.

Rates of out of hospital NT and out of hospital FT were compared as well as in-hospital outcomes. Thoracic decompression was defined as clinical documentation by EMS providers of a rush of air or fluid upon placement of a needle decompression catheter. Similarly, successful determination of thoracic decompression by FT was based on out of hospital provider documentation of a rush of air or blood upon insertion of gloved finger after FT. Subgroup comparison of the crossover group (i.e., those that received NT and subsequent FT) were compared to those that received NT alone. Data collected regarding rates of thoracic decompression were obtained review of out of hospital records and clinical exam by out of hospital or trauma surgery providers.

Wilcoxon Rank Sum Test and Chi-Squared Analyses were performed for comparison of out of hospital and in-hospital outcome variables. Groups were matched based on demographic and injury characteristics to control for differences in sex, age, BMI, and injury severity. Case-control matching was performed in SPSS (IBM Corp. Released 2021. IBM SPSS Statistics for Windows, Version 28.0. Armonk, NY: IBM Corp) with appropriate match tolerance for each included variable to create a matched cohort. Of subjects that met inclusion, 58 NT subjects were initially analyzed for matching. After matching 19 subjects from each cohort, four subjects were removed from the FT group due to chart review revealing inaccurate documentation of the performance of FT. All comparative statistical analyses were performed using SPSS.

**RESULTS**

Retrospective analysis was performed on a total of 34 patients, of which 15 (44.1%) underwent FT and 19 (55.9%) underwent NT without subsequent FT. Of the 15 FT subjects, six underwent attempt of NT prior to FT. Groups were well matched in terms of demographic factors and injury characteristics. There were no statistical differences in terms of age (p=0.30), sex (p=0.70), BMI (p=0.54), blunt mechanism rate (p=0.151), ISS (p=0.76), and chest AIS (p=0.29). See Table 1 for full tabulation of demographics and injury characteristics.

There was a significantly higher number of patients in the FT group that sustained out of hospital cardiac arrest (15 vs 6, p=0.001). Of those patients there was a higher percentage of patient in the NT group that achieved ROSC (66.7% vs 20.0%, p=0.040). See Table 2 for full results tabulation of out of hospital hemodynamic parameters.

| | All (n=34)[1] | FT (n=15)[1] | NT (n=19)[1] | p-value[2] |
|---|---|---|---|---|
| Age | 41.6 (18.2) | 39.1 (20.7) | 43.5 (16.4) | 0.494 |
| Male Sex | 26 (76.5) | 11 (73.3) | 15 (78.9) | 0.702 |
| BMI[3] | 28.1 (7.1) | 30.1 (9.4) | 26.6 (4.0) | 0.153 |
| Blunt Mechanism | 23 (67.6) | 8 (53.3) | 15 (78.9) | 0.151 |
| ISS[3] | 35.6 (18.2) | 36.3 (23.2) | 35.0 (13.6) | 0.843 |
| Chest AIS[3] | 3.56 (1.28) | 3.87 (1.60) | 3.32 (0.95) | 0.219 |
| On Scene Time[4] | 14.6 (9.2) | 12.4 (4.3) | 16.4 (11.5) | 0.209 |
| Total Transport Time[4] | 40.3 (17.5) | 36.8 (18.0) | 43.0 (17.1) | 0.317 |

[1]Variables represented as n (%) or mean (SD).
[2]Variables compared using Chi-squared analysis (categorical) or Mann U Whitney Test (continuous).
[3]BMI: body mass index, ISS: injury severity score, AIS: abbreviated injury scale
[4]Transport times expressed in minutes

*Table 1.* Comparison of demographics and injury characteristics of matched cohort.

| | All (n=34)[1] | FT (n=15)[1] | NT (n=19)[1] | p-value[2] |
|---|---|---|---|---|
| HR[3] | 88 (0, 123) | 0 (0, 133) | 108 (92, 132) | 0.001 |
| SBP[3] | 73 (0, 108) | 0 (0, 60) | 98 (88, 116) | 0.009 |
| Shock Index | 1.14 (0.89, 1.43) | 1.59 (0, 1.71) | 1.14 (0.89, 1.34) | 0.487 |
| PH[3] Cardiac Arrest | 21 (61.8) | 15(100.0) | 6 (31.6) | 0.001 |
| ROSC[3] | 7 (33.3) | 3 (20.0) | 4 (66.7) | 0.040 |

[1]Variables represented as n (%) or median (IQR).
[2]Variables compared using Chi-squared analysis (categorical) or Mann U Whitney Test (continuous).
[3]ROSC: return of spontaneous circulation; PH: prehospital; HR: heart rate; SBP: systolic blood pressure

*Table 2.* Comparison of out of hospital hemodynamics.

The two groups were also compared for in-hospital outcomes and further thoracic interventions. The FT group had a significantly higher rate of successful thoracic decompression compared to the NT group (93.3% vs 47.4%, p=0.004). Of the subjects that obtained cross sectional imaging after arrival, it was noted that one subject in the NT group sustained a subclavian artery injury after placement of NT. Although this was originally documented as a rush of fluid, this was later deemed to be unsuccessful intrathoracic decompression therefore was not included in the 9 subjects in the NT group with successful intrathoracic decompression. There was a significantly higher percentage of patients in the NT group (p=0.005) requiring subsequent tube thoracostomy placement after initial intervention, although this is not unexpected as NT is not a definitive treatment and it is expected that these patients undergo definitive thoracic decompression or operative intervention if indicated after arrival to the hospital.

Overall, 66.7% (n=10) of FT subjects and 94.7% of NT subjects required further thoracic interventions after the initial intervention. In the FT group, 8 subjects (53.3%) went on to receive chest tube and/or resuscitative thoracotomy. Only 1 subject in the FT underwent thoracotomy in the OR, but this is likely attributable to the high mortality rate in this group. Of the 18 subjects that required further thoracic intervention in the NT group, 18 required chest tube placement and 9 (47.4%) required resuscitative thoracotomy. There was no difference in the rate of resuscitative thoracotomy performed between the groups (p=0.730). There was a higher percentage of patients in the NT group that required thoracotomy in the operating room (p=0.001), although this may be affected by a higher rate of FT patients that expired prior to being transported to the operating room. There was no difference in mortality between the groups (86.7% vs 68.4%, p=0.213). See Table 3 for full tabulation of results.

| | FT (n=15)[1] | NT (n=19)[1] | p-value[2] |
|---|---|---|---|
| **Thoracic Decompression** | 14 (93.3) | 9 (47.4) | 0.004 |
| **Chest Tube Placement** | 8 (53.0) | 18 (94.7) | 0.005 |
| **Resuscitative Thoracotomy** | 8 (53.0) | 9 (47.4) | 0.730 |
| **Thoracotomy in OR** | 1 (6.7) | 12 (63.2) | 0.001 |
| **Mortality[3]** | 13 (86.7) | 13 (68.4) | 0.213 |

[1]Variables represented as n (%) or median (IQR).
[2]Variables compared using Chi-squared analysis (categorical) or Mann U Whitney Test (continuous). 3Representative of in-hospital mortality, all of which occurred within 48 hours of presentation.

*Table 3.* Comparison of thoracic decompression and in-hospital outcomes.

Subgroup analysis was performed for the crossover group (i.e., subjects that received NT and then subsequent FT) and compared to patients who received NT alone. Of the 15 out of hospital FT patients, 6 (40%) also underwent NT. There was no significant difference (all p>0.05) in terms of age, sex distribution, EMS on-scene time, EMS total transport time, ISS, or AIS Chest. Additionally, there were no observed differences between the crossover group and the FT only group in terms of arrival SBP, HR, or shock index. There was no significant difference between the groups in terms of in hospital outcomes (vent days, ICU days, hospital LOS, all p>0.05). There was also no significant difference between the groups in terms of requirements for chest tube placement (p=0.833), resuscitative thoracotomy (p=0.833), OR thoracotomy (p=0.205), or mortality (24-hour and 30-day; p=0.525 and 0.143, respectively).

**DISCUSSION**

This study supports the growing body of literature in support of FT as a viable alternative for out of hospital thoracic decompression due to its relative reliability for thoracic decompression (Wernick, 2015). No techniques are used in isolation, as there may be some advantages to utilization of NT, such as in those patients with large body habitus where a gloved finger may not be able to reach into the thoracic cavity. Neither of these techniques are definitive management for pneumothorax, but this study shows that not only was FT more successful in thoracic decompression, but also there were no differences in transport time, thus this technique does not contribute to any delays in definitive management. It was noted that based on provider discretion there were subjects that originally received NT, but subsequently required FT. When looking at the group that crossed over to the FT group (originally treated with needle decompression), there were no significant differences between the groups in terms of arrival characteristics, in hospital procedures, outcomes, or mortality. Overall, this comparison further supports the use of FT as a first line or second line alternative, but this study was not specifically intended to detect differences between these groups. Further analysis with a larger cohort is needed to make a definitive determination.

Although not statistically different, there was a trend towards short on-scene and total transport times in favor of FT suggest a possible area of further investigation. In future studies, this should be specifically analyzed to determine if transport times are different between these two procedures may impact outcomes as they are allowing for more rapid presentation to definitive trauma care.

There is a widespread range of success of NT in the out of hospital setting. Lesperance and colleagues (Lesperance, 2018) showed a range of successful needle decompression of 24% to 61%. This study showed a rate similar to this and other studies and is consistent with the current literature. This relatively low success rate is postulated to be secondary to a variety of factors including challenging conditions in out of hospital transport, chests wall anatomy (Martin, 2012; Laan, 2016), and concomitant traumatic injuries. Each method of thoracic decompression has its benefits and pitfalls, therefore clinical judgement centered on a patient-specific approach is warranted as this study cannot make a definitive statement to the best method for all patients.

**LIMITATIONS**

This cohort is small and severely injured in terms of chest trauma with a high mortality rate. Future prospective multicenter trials are necessary to further evaluate mortality and outcomes to make any definitive conclusions regarding the preferred technique. Another limitation to this study was the fact that all the FT group subjects sustained out of hospital cardiac arrest. Although in the matched groups, there was no difference in ISS or chest AIS scores, the significantly higher number of subjects in PH cardiac arrest in the FT group compared to the NT group suggests these patients were more severely injured. Evans and colleagues (Evans, 2016) estimate an overall rate of survival to hospital discharge of 6.3% in those that sustained out of hospital traumatic arrest, with a higher percentage of survival in those that sustain blunt injury. In this study, all subjects of the FT group sustained cardiac arrest compared to 6 out of 19 in the NT group, thus suggesting a possible higher severity of injury. Therefore, the significantly higher percentage of patients that obtained ROSC in the NT group is not unexpected and likely due to injury severity factors as opposed to factors related to the method of thoracic decompression. Future studies are warranted comparing groups with and without out of hospital arrest to better compare these methods of thoracic decompression.

No autopsies were performed in these patients, thus potential life-threatening injuries, if present, were unable to be obtained. As noted previously, upon further review of post-arrival imaging one subject in the NT group sustained a subclavian artery injury that was mistaken for decompression of a hemothorax, while no patients in the FT group had documentation of thoracic organ or great vessel injury. Although this finding is notable, no definitive claim can be made regarding the safety profile of NT and FT as this study is underpowered to detect a difference. Future, large-scale studies focusing on complications of out of hospital thoracic decompression are warranted. In a larger cohort with additional post-mortem examination, there may be potential to identify any injuries that may have been sustained from out of hospital thoracic decompression. True incidence of tube thoracostomy or resuscitative/operative thoracotomy are unknown as some subjects were deceased or has higher level procedures performed before other procedures could be performed (i.e., resuscitative thoracotomy performed before chest tube placement). Lastly, subjective confirmation of successful placement of NT and FT were utilized, which does introduce a certain degree of bias, but this was done as the authors deemed it inappropriate to compare a radiologic confirmation of NT placement with a subjective confirmation of FT by the provider.

## CONCLUSIONS

As the practice becomes more widespread, comparisons for FT and NT in patients with less significant chest trauma may yield additional results compared to this cohort, given the high severity of chest wall trauma and overall injury severity in this group. Additionally, a randomized trial in which patients are either treated with NT or FT may be beneficial to see the potential differences in efficacy of thoracic decompression. Continued education of out of hospital providers is necessary to educate them on alternatives to the current standard of care, especially if this technique is unsuccessful. There is a significant variability in the current literature regarding success of thoracic decompression by NT (Martin, 2012; Laan, 2016), therefore it is vital to re-assess our current standards for better alternatives to have improved patient outcomes. Additionally, with the increasing scope of out of hospital providers and the ability to perform additional procedures, our institution has deemed it vital that the standard techniques have mechanisms of quality control measures in place (e.g., reporting of rates of successful thoracic decompression or major injury from NT) to allow for process improvement.

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