Prehospital Decompression of Pneumothorax: A Systematic Review of Recent Evidence

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Conflicts of interest: none

Keywords: decompression; pneumothorax; prehospital; thoracic injuries; thoracostomy

Abbreviations:
AAL: anterior axillary line
BMI: body mass index
CT: computed tomography
CTP: chest tube placement
CWT: chest wall thickness
ED: emergency department
FT: finger thoracostomy
ICS: intercostal space
MAL: mid-axillary line
MCL: mid-clavicular line
MRI: medical resonance imaging
NCD: needle chest decompression
ROSC: return of spontaneous circulation

Received: December 16, 2020
Revised: February 16, 2021
Accepted: February 27, 2021

Abstract

Introduction: Pneumothorax remains an important cause of preventable trauma death. The aim of this systematic review is to synthesize the recent evidence on the efficacy, patient outcomes, and adverse events of different chest decompression approaches relevant to the out-of-hospital setting.

Methods: A comprehensive literature search was performed using five databases (from January 1, 2014 through June 15, 2020). To be considered eligible, studies required to report original data on decompression of suspected or proven traumatic pneumothorax and be considered relevant to the prehospital context. They also required to be conducted mostly on an adult population (expected more than ≥80% of the population ≥16 years old) of patients. Needle chest decompression (NCD), finger thoracostomy (FT), and tube thoracostomy were considered. No meta-analysis was performed. Level of evidence was assigned using the Harbour and Miller system.

Results: A total of 1,420 citations were obtained by the search strategy, of which 20 studies were included. Overall, the level of evidence was low. Eleven studies reported on the efficacy and patient outcomes following chest decompression. The most studied technique was NCD (n = 7), followed by FT (n = 5). Definitions of a successful chest decompression were heterogeneous. Subjective improvement following NCD ranged between 18% and 86% (n = 6). Successful FT was reported for between 9.7% and 32.0% of interventions following a traumatic cardiac arrest. Adverse events were infrequently reported. Nine studies presented only on anatomical measures with predicted failure and success. The mean anterior chest wall thickness (CWT) was larger than the lateral CWT in all studies except one. The predicted success rate of NCD ranged between 90% and 100% when using needle >7cm (n = 7) both for the lateral and anterior approaches. The reported risk of iatrogenic injuries was higher for the lateral approach, mostly on the left side because of the proximity with the heart.

Conclusions: Based on observational studies with a low level of evidence, prehospital NCD should be performed using a needle >7cm length with either a lateral or anterior approach. While FT is an interesting diagnostic and therapeutic approach, evidence on the success rates and complications is limited. High-quality studies are required to determine the optimal chest decompression approach applicable in the out-of-hospital setting.

Robitaille-Fortin M, Norman S, Archer T, Mercier E. Prehospital decompression of pneumothorax: a systematic review of recent evidence. *Prehosp Disaster Med.* 2021;36(4):450–459.

Introduction

Approximately 75% of all trauma deaths now occur out-of-hospital.[1,2] Of these deaths, it is estimated that 20% can be potentially prevented, and thoracic injuries remain one of the leading causes of early preventable trauma-related mortality.[2,3] Pneumothoraxes are potentially life-threatening injuries that require prompt identification and treatment, but they can be highly challenging to diagnose and address during prehospital care.[4]

doi:10.1017/S1049023X21000509

Health care professionals can use different strategies to decompress a proven or suspected pneumothorax.[5] Historically, in the out-of-hospital setting, needle chest decompression (NCD) at the second intercostal space (ICS) at the midclavicular line (MCL) has been the initial temporizing approach recommended by well-established associations such as Prehospital Trauma Life Support (PHTLS) and International Trauma Life Support (ITLS).[6,7] However, there has been a growing number of studies highlighting some limitations relative to the efficacy and safety of this approach.[4,5,8] The inability to reach the pleural space and the risk of catheter obstruction or dislodgment preventing the continuous decompression effect have been described, along with the risk of iatrogenic injuries by a misplaced needle.[4,9–11] Furthermore, it is practically impossible for the prehospital provider to know if the absence of a response to NCD is because the technique has failed or due to the absence of pneumothorax. Following traumatic cardiac arrest, this confusion can theoretically lead to inadequate termination of resuscitation and preventable mortality.[12] In recent years, alternative needle size, gauge, and insertion sites have been proposed and implemented around the world, along with different chest decompression techniques such as finger thoracostomy (FT) and chest tube placement (CTP), but there is a lack of consensus on the efficacy and safety profile of these different approaches, particularly in the prehospital setting.[11–13]

The aim of this systematic review is to synthesize the recent evidence on the efficacy, patient outcomes, and adverse events of different chest decompression approaches relevant to the out-of-hospital setting.

Methods

Data Source

A literature search strategy using a Boolean approach was developed and applied to PubMed (National Center for Biotechnology Information, National Institutes of Health; Bethesda, Maryland USA), Medline Ovid (US National Library of Medicine, National Institutes of Health; Bethesda, Maryland USA), Web of Science (Thomson Reuters; New York, New York USA), Cochrane (The Cochrane Collaboration; London, United Kingdom), and CINAHL (EBSCO Information Services; Ipswich, Massachusetts USA). MeSH and Entree terms were used for their respective databases (last updated June 15, 2020). Two relevant systematic reviews[14,15] on the topic were published, but they have limited their search to studies published prior to 2015. To review the newest evidence, the search strategy was limited to studies published after January 1, 2014. The search strategy terms included: (1) Catheter OR Needle OR Finger OR Simple or Novel Device OR (Modified Veress) OR (Colorimetric Capnography) OR Trocar; (2) Thoracostomy OR Decompression OR Thoracentesis; (3) Pneumothor* OR (Tension AND Pneumothor*) OR Complication* OR Adverse Event* OR Success*; (4) Pre-Hospital OR Out of Hospital OR Emergency Medical Service* OR EMS OR Paramedic Emergency Medical Technician* OR EMT; (5) (Tube AND Thoracostomy) OR (Chest AND Tube). The first search combined one and two and three, and the second search combined three and four and five. The search strategy was limited to human studies published in English or French. Google Scholar (Google Inc.; Mountain View, California USA; first 100 results) was also scrutinized for additional potentially eligible studies. Finally, references from included studies and previous narrative reviews were scrutinized looking for potential additional studies as well as abstract from relevant conferences.

Eligibility Criteria

To be considered eligible, studies required to report original data on decompression of suspected or proven traumatic pneumothorax and to be considered relevant to the prehospital context. They were also required to be conducted mostly on an adult population (expected more than ≥ 80% of the population ≥ 16 years and older) of patients. Animal or cadaver studies, case reports, as well as opinion piece, letter, comment, or abstract only available data were excluded.

Study Selection and Data Extraction

One researcher (MRF) reviewed sequentially all the titles and abstracts of the retrieved citations. Manuscripts of potentially relevant studies were thereafter fully reviewed, screening for eligibility based on the inclusion and exclusion criteria. Other authors (TA or SN) confirmed the eligibility of the included studies. Relevant data were extracted using a pre-piloted Word (Microsoft Corp.; Redmond, Washington USA) form. Extracted data included variables relative to the study design, country of origin, setting, and relevant results.

Reporting

This review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Appendix 1; available online only).[16] Given the anticipated clinical heterogeneity relative to the population included, chest decompression approaches, and outcomes, no meta-analytic approach was considered appropriate when the study protocol was developed.

To report the results, included studies were divided into two pre-determined categories. First, studies performed in a clinical setting and reporting on the efficacity, patient outcomes, and/or adverse events were grouped and synthesized. Then, studies limited to anatomical measures and their associated success and failure rates, using radiological data (for instance, studies limited to chest wall thickness [CWT] measures), were grouped and synthesized.

Grade of Evidence

Every retained article was appraised using the Critical Appraisal Skills Program (CASP)[17] and a level of evidence was subsequently assigned to each study by the author using the Harbour and Miller system, which aims to determine the level of evidence.[18]

Results

Characteristics of Included Studies

A total of 1,420 unique citations were obtained by the literature search strategy, of which 20 original studies (two prospective cohort or case series and 18 retrospective cohort or cases series) fulfilled the inclusion criteria.[19–38] Each study included between 24 and 2,574 patients and most studies (n = 9) were conducted in the United States of America. The main mechanism was blunt trauma. Twelve studies presented data on efficacy, patient outcomes, and/or adverse events,[19–29,36] while ten studies presented findings limited to anatomical measures and predicted success rate and outcomes (two studies presented results relevant to both categories).[19,30–38] Characteristics of the included studies are presented in Table 1 and Table 2.

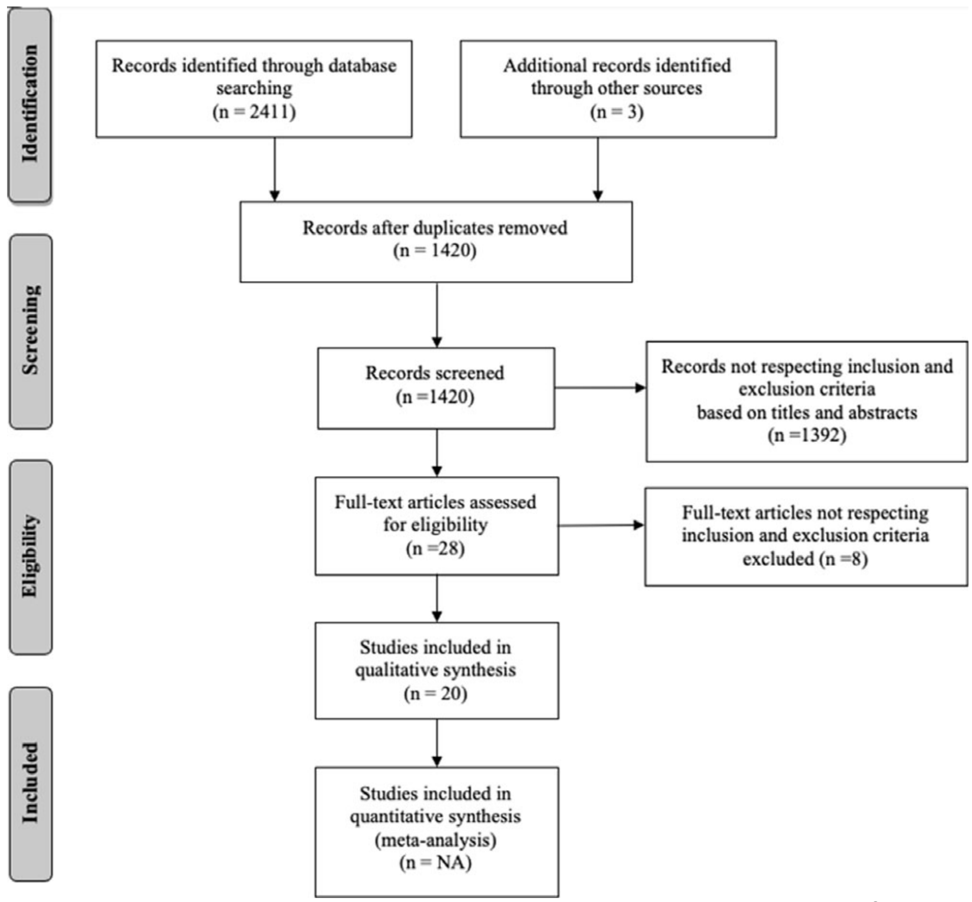

Figure 1. Flow Diagram.

Efficacy, Clinical Outcomes, and Adverse Events

The most clinically studied chest decompression technique was NCD (n = 7),[19–21,23,26,28,29] followed by FT (n = 5)[22–25,27] and CTP (n = 3).[21,25,26] Overall, the success rate of NCD ranged between 18% and 86%.[19,21,26] In general, criteria used to define a successful NCD were heterogeneous as studies included variables such as improvement in vital signs, improvement in oxygenation, a gush of air during the procedure, improved lung compliance, or improved air entry on chest auscultation.

Using a comparison of two needle lengths, Aho, et al reported a non-significant improved success rate using an 8cm (83%) versus a 5cm (62%) needle in the prehospital field (P <.28).[19] Using CWT measures of patients whose imaging data were available and who underwent chest decompression in the prehospital or hospital setting (n = 49), success rates of 80% and 100% were predicted using respectively the 5cm and 8cm needles compared to the 41% and 83% real-time clinical performance. This illustrates the discordance between the radiographical prediction of success and actual clinical improvement.[19] Following the prehospital implementation of NCD in a study including mostly hemodynamically stable patients (92%), no modifications of vital signs following the procedure were reported except for an increased oxygen saturation (P = .002).[20] Three studies found a statistically significant mortality decrease when NCD was reported successful by the prehospital clinician.[19,28,29] The mortality was not associated with the needle length.[19,28]

Using FT, the decompression success rate ranged between 9.7% to 32.0%.[22–25,27] In a case series of 250 patients following FT or CTP, the reported improvement rate was 30%.[25] One study found an improved oxygen saturation at hospital arrival compared to the on-field oxygen saturation prior to FT (P = .003).[20,22] In a case series of six patients, CTP was reported successful during 83% of prehospital interventions for patients with a tension pneumothorax.[26] Four studies reported a return of spontaneous circulation (ROSC) rate between 15.7% and 25.0% with associated survival from 0.6% to 9.4% for traumatic cardiac arrest following prehospital FT.[23–25,27] A single study reporting on six patients following the prehospital use of a 10 French Vygon thoracic trocar and drain catheter did not present data on patient outcomes.[21]

Most studies (n = 6)[19,21,22,27–29] did not report any adverse events or complications relative to chest decompression. One study reported three significant iatrogenic events, including one iatrogenic pneumothorax, one hematoma, and one vessel injury causing a hemothorax following NCD at 2ICS-MCL.[20] In the same study, patients who had a computed tomography (CT) scan with the catheter still in place on hospital arrival, 94% (48/51) of the catheter's tips were hanging outside of the pleura. Similarly, Lesperance, et al reported that 76% of the NCD catheters were more than 5mm away from the pleura on the imaging performed in the emergency department (ED).[36] Four studies reported that between 18% and 42% of patients did not have any evidence of pneumothorax on ED admission imaging following prehospital

Clinical Studies	Grade of Evidence	Radiological Studies	Grade of Evidence
Aho, et al (2016)	2-	Blenkinsop, et al (2015)	3
Axtman, et al (2019)	3	Chang, et al (2014)	3
Chen, et al (2015)	3	Chanthawatthanarak (2019)	3
Chesters, et al (2016)	3	Goh, et al (2018)	3
Dickson, et al (2017)	2-	Hecker, et al (2016)	3
Hannon, et al (2020)	3	Lamblin, et al (2014)	3
High, et al (2016)	3	Lesperance, et al (2018)	3
Kaserer, et al (2017)	3	Powers, et al (2014)	3
Peters, et al (2017)	3	Sirikun, et al (2017)	3
Weichenthal, et al (2016)	3		
Weichenthal, et al (2018)	2-		

Table 3. Level of Evidence of Included Studies

chest decompression attempt.[20,24,26,36] High, et al reported nine complications (3.6%), including eight chest tube misplacements and one empyema, in their cohort of 250 patients.[25] In a cohort of 57 patients with prehospital FT, three complications (5.2%) were reported, including two failures to reach the pleura and one concomitant laceration of the diaphragm and liver.[23] Kaserer, et al found three chest tube misplacements or dislodgments which represent 50% of their cohort. Hannon, et al reported three adverse events (4.8%), including one cellulitis, one vessel injury with arterial bleed, and one diaphragmatic and a liver laceration in their cohort of FT. Finally, Dickson, et al and Peters, et al specified that no procedural injuries to the clinicians were reported with the use of a scalpel for FT in their case series.

Anatomical Measures and Predicted Success Rate

Ten studies presented data on anatomical measures predicting the association between chances of success or failure and different chest decompression approaches (Table 2).[19,30–38] These studies mostly included civilians (n = 4,304) and military personnel (n = 185). Measurements in all studies were performed using CT, except for Lamblin, et al[35] who used ultrasound and Hecker, et al who used magnetic resonance imaging (MRI).[34]

All ten studies reported the mean CWT at various anatomical sites and the associated potential success or failure rates using NCD. To determine the potential success rate associated with a puncture site, studies compared the measured CWT to a pre-determined needle size (usually 5cm or 8cm). If the needle was long enough to theoretically penetrate the CWT, the procedure was considered as a potentially successful procedure, and if not, the procedure was considered as a potential failure. Four studies also determined the risk of iatrogenic injury by calculating the distance to the nearest critical organ from the needle penetration point with 90 degrees penetration angle (n = 2)[30,31] and/or without restricting the angle of penetration (n = 4).[30,31,36,38]

Eight studies made statistical comparisons between the anterior and lateral sites.[19,30–33,36,38] All reported a thinner CWT for lateral sites except for Aho, et al and Chanthawatthanarak, et al who found the opposite.[19,32] When comparing the predicted failure rate, most of the studies found a predicted higher failure rate at 2ICS-MCL compared to lateral sites when using a 5cm needle, but none reported a statistically significant higher failure rate when using needle >7cm. Specifically, for decompressions performed at the 2ICS-MCL, the failure rate ranged between 2.6% and 93.0% with a 5cm needle.[30,32,33,35,36,38] The highest failure rate was reported for a cohort of American patients with a body mass index (BMI) >30[37] while the lowest rate was for a cohort of Thai patients.[32] Using lateral decompression sites, the predicted failure rate ranged between 0% to 47%.[30,32,33,35,36,38] When using needles >7cm, the predicted failure rate ranged between 0% and 5% for anterior decompression sites[30,31,33,34,36] and between 0% and 10% for the lateral decompression sites.[30,31,36]

Only four studies reported on the potential risk of adverse events.[30,31,36,38] The highest risk was always for the left puncture sites. Sirikun, et al report a 2.9% risk of injury to the mediastinum with a 5cm needle at 2ICS-MCL.[38] Chang, et al reported a risk of organ injury of 0% with a 5cm needle and up to 9% with an 8cm needle at 2ICS-MCL ($P > .05$).[31] For the lateral approach, the risk of iatrogenic injury ranged between 0% and 1% with a 5cm needle and between 9.0% and 48.1% with an 8cm needle on the left side.[30,31,36,38] The heart was the organ at highest risk for left lateral NCD.[31,36] The predicted risk of serious adverse events was statistically higher using lateral decompression sites compared to anterior sites in one study ($P < .05$).[31]

Level of Evidence

Overall, using the Harbour and Miller appraisal tool, the level of evidence assessment showed that most included studies were considered Grade 3 (Table 3).

Discussion

This systematic review of the recent literature relative to chest decompression in the out-of-hospital field highlights the low-grade evidence relative to different approaches such as NCD and FT to decompress a potential pneumothorax despite their wide-spread use. When NCD is the chosen approach, recent evidence showed that the failure rate can be as high as 93% with 5cm needle compared to 10% with longer needles (>7cm). While FT is a promising technique, data are limited at the moment, particularly relative to its success, impact on patient-important outcomes, and complication rates.

The most studied chest decompression technique remains NCD,[19–21,23,26,28,29] while five studies reported on FT[22–25,27] and three reported some data on CTP.[21,25,26] Both FT and CTP require a higher level of training and are more invasive than NCD, especially for alert and spontaneously breathing patients. On the other hand, FT is interesting because it is diagnostic as well as therapeutic.[39] Establishing the diagnosis and monitoring its cardiovascular and respiratory impacts after chest decompression is critical when trying to stabilize a critically ill trauma patient.[40] The reported success rate of FT ranged between 9.7% to 32.0% but with heterogeneous definitions of success and a large number of patients in traumatic cardiac arrest. The success rate was associated with the patient's clinical improvement following the procedure and not the capacity to access the pleural space. The most significant reported adverse event was a liver injury.[24] Studies published before this systematic review have reported a rate of clinical improvement as high as 100%[41] following the procedure and a relatively low rate of complications[12,13,41,42] in studies with small sample sizes and high risk of bias.

When NCD is used, the risk of severe adverse events seemed higher for lateral decompression sites, particularly for the left lateral approach with the proximity of the heart,[30,31,36,38] but only one study reported a statistically significant predicted increase risk of iatrogenic injuries compared to the standard anterior approach.[31] The risk of adverse events is an important consideration to choose the optimal decompression technique. However, as highlighted by two included studies, the predicted success and complication rates based on anatomic measures are different from those obtained on the field.[31,36] Therefore, the risk of serious adverse event might be over-estimated for imaging studies.[31,36] Two studies showed that a large proportion of the needle tips on arrival to the hospital were outside the pleura, reflecting either a high placement failure or a high catheter displacement rate after NCD.[20,36] No included study was powered to detect a statistically significant difference in complication rates between the interventions and no studies used a standardized and systematic approach to look for immediate complications of chest decompression. Therefore, the exact safety profile of NCD remains unclear. Furthermore, four studies reported that between 18% and 42% of the patients did not present any signs of pneumothorax on the imaging performed in the ED. Establishing the correct diagnosis is critical and the lack of strong diagnostic tool has an impact on the perceived efficacy and safety of the different chest decompression techniques. Accurate diagnosis is also important to avoid harm associated with unnecessary procedures such as chest decompression. These data raise doubts regarding the historical teaching that tension pneumothorax should be diagnosed clinically. Implementation of prehospital ultrasound can be an interesting diagnostic area to assist clinician decision making.[43,44]

The lateral CWT at the 4-5ICS-mid-axillary line (MAL) or the 4-5ICS-anterior axillary line (AAL) was often thinner than the anterior 2ICS-MCL. Presented CWT measures of the studies included in this review were similar to those described in the recent systematic review and meta-analysis conducted by Clemency, et al and Laan, et al.[14,15] Using studies published from 2005 through 2014, the two reviews found a mean CWT of 42.50mm (SD = 13.80) and 42.79mm (95% CI, 38.78-46.81) compared to 39.85mm (95% CI, 28.70-51.00) and 34.33mm (95% CI, 28.20-40.47) at the 4-5ICS-MAL or the 4-5ICS-AAL, respectively.[14,15] Those two systematic reviews published in 2015 and 2016 reported that a catheter longer than 6.44cm would be required to decompress 95% of patient's anterior chest and that lateral NCD have a higher predicted rate of success for decompression with any sort of needle due to the thinner chest wall at this location.[14,15] The clinical significance of a thinner chest wall is limited since the expected failure rate is similar at both sites when using a sufficiently long needle (>7cm). This seems to be the case regardless of patient sex.[34] The thinner lateral CWT could be meaningful in scenarios such as patients with an unusually large CWT due to a high BMI as there is a correlation between these two variables.[19,31,33,37,38] Lateral decompression approaches may be clinically useful in situations where anterior placement is impossible due to injuries or physical constraint such as bulletproof vest in an active shooting situation. The optimal needle gauge was not studied explicitly in any of the included studies, so no data are available to support the use of a bigger or smaller gauge than the standard 14-gauge needle. The absence of data is a problem because the needle gauge and length may be directly related to its capacity to decompress a tension pneumothorax.[45]

Limitations

The methodological quality of the included studies was limited. No randomized control trial has been recently published on the subject and so, the study designs are weak according to the hierarchy of evidence of Miller and Harbour. Only two of the presented studies carried out a power analysis.[32,38] Furthermore, the criteria for a successful procedure used were heterogeneous and often subjective. The level of training of the clinicians was also heterogeneous, which can potentially impact the external validity. Additionally, the chest decompression procedures were conducted without formal proof of the presence of the disease, meaning that the absence of treatment effect, in some situations, might have been due to the absence of the disease in the first place. Moreover, some of the cohort studies did not control for confounders, such as associated injuries, and were prone to patient's selection bias. The patient outcomes and adverse events presented were not standardized and were heterogeneous. Finally, despite the author's best effort to include all relevant studies on the topic, selection bias cannot be completely excluded.

Conclusions

Based on the recent evidence, for optimal success, prehospital NCD should be performed using a needle >7cm length despite an associated theoretical higher risk of iatrogenic injuries. There is a paucity of evidence to support primarily the lateral approach compared to the anterior approach when an 8cm needle is used as the reported and predicted decompression success rates are similar. While FT is an interesting diagnostic and therapeutic approach with a reported clinically beneficial success rate ranging between 9.7% to 32.0%, results relative to patient-important outcomes and adverse events associated with FT are inconsistently reported in the literature. High-quality studies are required to further inform clinicians about the most beneficial chest decompression technique applicable in the out-of-hospital field.

Author Contributions

MRF had the original idea for this study. MRF conceived the study's design and protocol with support, input, and oversight from SN, TA, and EM. MRF and SN elaborated the original database search strategy. MRF performed the study selection and data extraction with oversight from EM. MRF wrote the manuscript first draft. All authors contributed substantially to the manuscript revision and they all approved the final submitted version. MRF is accountable for all aspects of this study.

Supplementary Materials

To view supplementary material for this article, please visit https://doi.org/10.1017/S1049023X21000509

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Study Country	Study Design	No. of Patients and No. of Decompression Sites	Inclusion Criteria	Chest Decompression Techniques	Efficacy	Patient Outcome	Adverse Event	Other Findings
Aho, et al (2016) USA	Retrospective Cohort Study (before and after)	n = 70 Patients n = 91 Decompression	>15 yo NCD in prehospital or resuscitation room (2003-2013)	NCD with 5cm vs 8cm needle at the 2ICS-MCL	Improvement following NCD 49.0% (68.3% prehospital vs 20.7% ED; P ≤.01) Prehospital success rate = 83.0% and 62% with 8cm vs needle 5cm (P = .28)	Mortality decreased for successful NCD (20.6% vs 44.4%; P = .03) No difference for 5cm vs 8cm needle (P = .46)	No AE reported	Discordant predicted and clinical success rate
Axtman, et al (2019) USA	Retrospective Case Series	n = 59 Patients n = 63 Decompression	>18 yo patients undergoing NCD (2014-2018)	Various type and size of NCD at the 2ICS-MCL	No difference in heart rate, systolic or blood pressure, and respiratory rate (P >.05) Improvement in SpO_2 following NCD (P = .0015)	NR	1 patient iatrogenic PTx 5 kinked catheters, 1 subcutaneous hematoma, 1 vascular injury	94.1% of needles were not within the pleural space on ED imaging 76.6% had a PTx confirmed in the ED
Chen, et al (2015) Israel	Retrospective Case Series NCD and Vygon Newborn CTP	n = 111 Patients n = 88 NCD n = 6 Vygon Catheter Placement	Patient with CD in the field (1997-2012)	Variable needle size NCD 10-French Vygon chest tubes	Subjective improvement in respiratory function following NCD in 83.0% of surviving and 86.0% of non-surviving patients NCD did not improved mortality rate	Overall mortality 51.0%	No AE reported	None
Chesters, et al (2016) United Kingdom	Retrospective Case Series	n = 126 Patients n = 236 Decompressions	Patient with CD (2010-2014)	FT	SpO_2 improved at hospital arrival compared to before (91.8% vs 97.2%; P = .003)	NR	No AE reported	None
Dickson, et al (2017) USA	Retrospective Cohort Study	n = 57 FT Patients n = 50 NCD Patients n = 100 FT Decompressions n = 50 NCD Decompressions	TCA during which FT was used (2013-2017)	FT vs NCD (unknown needle size)	FT: 32.0% had air return, 25.0% had ROSC, 11.0% survived 24h and 7.0% were discharged alive	FT vs NCD ROSC rate P = .4833 and survival rate P = .1212 7.0% neurologically intact survivor for FT 0.0% for NCD	Rate of AE 5.3% for FT but NR for NCD	Average transport time for NCD was 15.33 min vs 17.04 min for FT

Table 1. Characteristics of Studies on Efficacy, Patient Outcome, and Safety of Chest Decompression *(continued)*

Hannon, et al (2020) Australia	Retrospective Case Series	n = 103 Patients n = 179 Decompressions	Trauma patients undergoing FT performed by flight paramedics (2015-2018)	NCD performed by paramedics before HEMS arrival in 75.7% of cases followed by FT	NR	Following TCA in 32, 25 (78.1%) died prehospital, 4 (12.5%) died in hospital, and 3 (9.4%) survived	Rate of AE 4.8% (cellulitis, arterial injury, liver, and diaphragm laceration)	Imaging was performed before CTP for 38/73 patients (52.1%) of which 14 (42.0%) showed no PTx
High, et al (2016) USA	Retrospective Case Series	n = 250 Patients n = 421 Decompressions	>18 yo patients transported by EMS following FT or CTP (2006-2013)	FT or CTP	30% improved clinically following FT or CTP	163 patients (65.2%) required CPR; only 1 (0.58%) survived. 87 patients (34.8%) did not require CPR, 74 survived (85.1%)	Rate of AE 3.6% (misplaced or dislodged tube during transport 3.2% and one empyema 0.4%)	None
Kaserer, et al (2017) Switzerland	Retrospective Case Series	n = 24 Patients n = 17 NCD n = 6 CTP n = 1 NCD+CTP	Adult patients with CD who arrived to hospital (2009-2015)	NCD at 2CIS-MCL with 3.3-5.5cm needle CTP	Successful NCD in 18.0% according to paramedics Successful CTP was 83.0%	NR	Three chest tube misplacements or dislodgments (50.0%) No NCD AE	None
Peters, et al (2017) Netherlands	Retrospective Case Series	n = 144 Patients in TCA n = 267 FT	All patients following FT (2007-2014)	FT	Successful CD in 9.7% of the patients	15.3% had ROSC, of which 27.3% had a PTx evacuated, 2.8% survived initial resuscitation, 1.4% were discharged	No AE reported	None of the 4 patients who survived had a PTx evacuated by FT
Weichenthal, et al (2018) USA	Retrospective Cohort Study (before-after comparative)	n = 305 Patients n = 169 Patients 2ICS-MCL n = 136 Patients 5ICS-MAL	All patients with NCD (2007-2016)	Cohort 1: 14-gauge, 5cm needle at 2ICS-MCL Cohort 2: 9.5cm 10-gauge needle at 5 ICS-MAL	Clinical change after NCD improved mortality (P = .002; 95% CI, 0.013-0.386) No change in efficacy P = .993 or mortality P = .231 following modification of NCD protocol	Overall mortality 79.0% 2 patients survived TCA with disabilities	3 repeated NCD due to catheter dislodgement	Clinical improvement more frequent when conducted on alive patients compared to TCA P <.001
Weichenthal, et al (2016) USA	Retrospective Case Series	n = 169 Patients	All patients receiving NCD (2007-2013)	NCD with 5cm, 14-gauge needle at 2ICS-MCL	Clinical change after NCD was predictive of survival (P = .001)	Overall mortality 79.0% 1 patient survived TCA with disabilities	No AE reported	Alive patients were more likely to have a positive response to NCD (63 vs 24%; P <.001)

Table 1. *(continued).* Characteristics of Studies on Efficacy, Patient Outcome, and Safety of Chest Decompression
Abbreviations: ICS, intercostal space; MCL, mid-clavicular line; AAL, anterior axillary line; MAL, mid-axillary line; CD, chest decompression; CPR, cardiopulmonary resuscitation; ED, emergency department; AE, adverse event; CTP, chest tube placement; CT, computed tomography; FT, finger thoracostomy; PTx, pneumothorax; NCD, needle chest decompression; NR, not reported; SPO_2, peripheral capillary oxygen saturation; TCA, traumatic cardiac arrest; ROSC, return of spontaneous circulation; EMS, Emergency Medical Services; HEMS, helicopter Emergency Medical Services.

Study	Study Design Imaging Technique	No. of Patients and No. of Decompression Sites	Inclusion Criteria	Chest Decompression Techniques	Unweighted Mean CWT (mm)	Important Findings
Aho, et al (2016) USA	Retrospective Cohort Study (CT)	n = 49 Patients	>15 yo NCD in prehospital or resuscitation room (2003-2013)	5cm or 8cm needle	2ICS-MCL 41.0 4ICS-MAL 46.7	Difference between anterior and lateral CWT not significant P = .06 5cm and 8cm needle will decompress 80.0% and 100.0% at 2ICS-MCL 5cm and 8cm needle will decompress 53.0% and 90.0% at 4ICS-MAL
Blenkinsop, et al (2015) United Kingdom	Retrospective Case Series (CT)	n = 63 Patients Decompression Sites 126 2ICS-MCL 126 5ICS-MAL	Consecutive radiological imaging for patients requiring massive transfusion protocol (2008-2013)	4.5cm to 8cm needle	2ICS-MCL 37.14 5ICS-MAL 34.39	Left side 2ICS-MCL thicker than left side 5ICS-MAL (P = .009) 5.5cm needle will decompress 99.0% of cohort Proportion of predicted iatrogenic injury at 5ICS-MAL of 0.0% with 5cm needle vs 29.0% with 8cm needle
Chang, et al (2014) USA	Retrospective Case Series (CT)	n = 100 Patients Decompression Sites 200 2ICS-MCL 200 4ICS-AAL	Consecutive adult trauma patients at a Level I trauma ED (2011)	5cm and 8cm needle	2ICS-MCL 45.05 4ICS-AAL 39.75	2ICS-MCL thicker than 4ICS-AAL (no P value reported) No difference for radiological decompression success between 4ICS-AAL and 2ICS-MCL (P >.05) Higher risk of heart puncture with 8cm needle at 4ICS-AAL vs 2ICS-MCL (P <.05)
Chanthawatthanarak, et al (2019) Thailand	Retrospective Case Series (CT)	n = 155 Patients Decompression Sites 310 2ICS-MCL 310 5ICS-AAL	>18 yo needing a thoracic CT with no chest wall disease (2016-2017)	5cm needle	2ICS-MCL 26.98 5ICS-AAL 36.32	Statistically significant larger CWT at 5ICS-AAL vs 2ICS-MCL (P <.05) Increased BMI was associated with increased CWT and decreased predicted success rate (P <.001) Higher predicted success rate at 2ICS-MCL with 5cm needle compared to 5ICS-AAL (P < .001)
Goh, et al (2018) Singapore	Retrospective Case Series (CT)	n = 593 Patients Decompression Sites 1186 2ICS-MCL 1186 5ICS-MAL	>16 yo trauma patients with a thoracic CT admitted between (2011-2015)	5cm to 7cm needle	2ICS-MCL 39.8 5ICS-MAL 35.7	2ICS-MCL thicker and increased failure rate compared to 5ICS-MAL (P = .001) 2ICS-MCL 78.8% of 5cm needle would reach the pleura compared to 98.2% of 7cm needle 5ICS-MAL 88.2% of 5cm needle would reach pleura compared to 98.5% of 7cm needle
Hecker, et al (2016) Germany	Retrospective Case Series (MRI)	n = 2574 Patients Decompression Sites 5148 2ICS-MCL	Healthy volunteer with MRI data relative to CWT (2009-2012)	4.5cm to 9.3cm needle	2ICS-MCL 50.83	Failure rate 45.0% with 5cm compared to 1.0% with 9.3cm Low risk of internal mammary injury Women CWT thicker than men (P <.0001) Significant correlation between CWT and BMI (r = 0.73; P <.0001)

Table 2. Characteristics of Studies on Anatomical Measures *(continued)*

Lamblin, et al (2014) France	Prospective Case Series (Ultrasound)	n = 122 Patients Decompression sites 244 2ICS-MCL 244 4ICS-MAL	Soldier's recruitment process (2010)	5cm needle	2ICS-MCL 41.9 4ICS-MAL 30.0	2ICS-MCL thicker than 4ICS-MAL (P < .001) Predicted failure rate of 23.8% at 2ICS-MCL compared to 4.9% at 4ICS-MAL (P < .001)
Lesperance, et al (2018) USA	Retrospective Case Series (CT)	n = 335 Patients Decompression Sites 344 2ICS-MCL 344 5ICS-AAL	All patients admitted to trauma center with prehospital NCD (2005-2014)	Unknown size of field needle Radiological prediction with: 5cm or 8cm needle	Mean 2ICS-MCL 43.9 Mean 5ICS-AAL 37.55	2ICS-MCL thicker than 5ICS-AAL (P < .005) Injured side CWT thicker than non-injured side (P < .005) 8cm failure rate lower than 5cm (no P value reported) 39.1% of patients treated with NCD did not have any evidence of PTx on ED imaging (before CTP) Discordant clinical failure rate compared to radiological predictions Clinical NCD failure rate estimated to be between 39.0% and 76.0% 48.0% had the heart within reach at 5ICS-AAL with an 8cm needle
Powers, et al (2014) USA	Retrospective Case Series (CT)	n = 326 Patients Decompression Sites 652 2ICS-MCL	Adult trauma patients with a thoracic CT (2004-2006)	5cm needle	2ICS-MCL 62.5	Increasing BMI increased CWT (P <.0001) Higher failure rate with increased BMI Failure rate between 25.0% and 93.0%
Sirikun, et al (2017) Thailand	Prospective Case Series (CT)	n = 172 Patients Decompression Sites 344 2ICS-MCL 344 5ICS-MAL	>18 yo with a thoracic CT and without chest wall disease (2009)	3.75cm to 5cm needle	2ICS-MCL 34.95 5ICS-MAL 23.42	Female CWT thicker than male (P <.001) CWT correlated to BMI and body weight Mean 2ICS-MCL risk of mediastinal injury with 5cm needle 0.6% for right and 2.9% for left side 5cm needle may not reach pleura for 11.3% at 2ICS-MCL Failure rate ranged between 0.0% and 54.5%

Table 2. *(continued).* Characteristics of Studies on Anatomical Measures
Abbreviations: ICS, intercostal space; MCL, mid-clavicular line; AAL, anterior axillary line; MAL, mid-axillary line; AAL, anterior axillary line; ED, emergency department; BMI, body mass index; CT, computed tomography; CWT, chest wall thickness; PTx, pneumothorax; MRI, medical resonance imaging; NCD, needle chest decompression.