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Athanasios Chalkias
thanoschalkias@yahoo.gr

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CLINICAL REVIEW

Prehospital emergency thoracotomy: when to do it?

Athanasios F. Chalkias, MD
Department of General Medicine
TZANEIO General Hospital of Piraeus, Greece

Abstract
Traumatic injuries still constitute one of the leading causes of death in all age groups. Emergency thoracotomy is a procedure carried out in patients presenting in extremis. The primary goals are the control of massive hemorrhage, the release of cardiac tamponade, the internal or open cardiac massage, the prevention or control of air embolism, the control of bronchopleural fistulae and the cross-clamping of descending aorta. Although the usefulness of prehospital emergency thoracotomy remains controversial and specific guidelines are lacking, when faced with no alternative, it can be a lifesaving procedure. A comprehensive search for relevant studies was performed from 1975 to the present. An algorithm is proposed to assist physicians in deciding when to perform on scene thoracotomy.

Keywords: *algorithm; indications; prehospital emergency thoracotomy.*

Introduction
Today, traumatic injuries still constitute one of the leading causes of death in all age groups,[1] and while a majority of injuries can be managed non-operatively, initial resuscitation of traumatized patients may include specific invasive procedures such as emergency thoracotomy.[2–4]

Thoracotomy, a major surgical maneuver, is an incision of the chest wall. It is performed by trained physicians, to gain access to the thoracic organs. Resuscitative or emergency thoracotomy is a lifesaving procedure, when performed with the correct indications and approaches, and is defined as that occurring either immediately at the site of injury, in the emergency department or in the operating room, as an integral part of initial resuscitation.[5] The influence of prehospital emergency thoracotomy on mortality is not clearly defined and, thus, its usefulness remains controversial.[6–8]

A comprehensive search for relevant studies was performed in PubMed, Medline and Scopus databases from 1975 to the present using "*thoracotomy*", "*emergency*", "*trauma*", and "*prehospital*" as keywords. Cross-referencing was performed using the bibliographies from the articles obtained. The aim of this article is to present the indications and the techniques of the procedure as well as to propose an algorithm that will assist physicians in deciding when to perform on scene thoracotomy.

Indications of emergency thoracotomy

According to the ATLS (EMST in Australia) guidelines, emergency thoracotomy should be considered in patients with penetrating thoracic injuries and who arrive pulseless with myocardial electrical activity, but not for blunt trauma; however, some authors suggest that this intervention has a vital role in selected patients with blunt trauma patients.[9,10] In any case, the indications for blunt trauma remain controversial.[11]

In 2001, the American College of Surgeons Committee on Trauma has instituted Level II guidelines on emergency department thoracotomy (Tables 1–2).[11] The decision to perform the procedure is determined by the presence of signs of life and the mechanism and location of injury. Current indications and contraindications of emergency thoracotomy are seen in Table 3, while the primary goals of the procedure are seen in Table 4.

Table 1. Level II recommendations for emergency department thoracotomy from the American College of Surgeons Committee on Trauma.[11]

1. Emergency department thoracotomy should be performed rarely in patients sustaining cardiopulmonary arrest secondary to blunt trauma because of its very low survival rate and poor neurologic outcomes. It should be limited to those that arrive with vital signs at the trauma centre and experience a witnessed cardiopulmonary arrest.
2. Emergency department thoracotomy is best applied to patients sustaining penetrating cardiac injuries that arrive at trauma centres after a short scene and transport time, with witnessed or objectively measured physiologic parameters (signs of life): pupillary response, spontaneous ventilation, presence of carotid pulse, measurable or palpable blood pressure, extremity movement, and cardiac electrical activity.
3. Emergency department thoracotomy should be performed in patients sustaining penetrating non-cardiac thoracic injuries, but these patients generally experience a low survival rate. Because it is difficult to ascertain whether the injuries are non-cardiac thoracic versus cardiac, emergency department thoracotomy can be used to establish the diagnosis.
4. Emergency department thoracotomy should be performed in patients sustaining exsanguinating abdominal vascular injuries, but these patients generally experience a low survival rate. Judicious selection of patients should be exercised. This procedure should be used as an adjunct to definitive repair of the abdominal-vascular injury.
5. For the paediatric population guidelines 1-4 are applicable.

Table 2. Guideline recommendation and evidence grading (GREG).

A. Evidence grade:

1. (High): the described effect is plausible, precisely quantified and not vulnerable to bias.
2. (Intermediate): the described effect is plausible but is not quantified precisely or may be vulnerable to bias.
3. (Low): concerns about plausibility or vulnerability to bias severely limit the value of the effect being described and quantified.

B. Recommendation grade:

- (Recommendation): there is robust evidence to recommend a pattern of care.
- (Provisional recommendation): on balance of evidence, a pattern of care is recommended with caution.
- (Consensus opinion): evidence being inadequate, a pattern of care is recommended by consensus.

Table 3. Indications and contraindications of emergency thoracotomy.

A. Indications

1. Penetrating thoracic injury with the following conditions:
   - Previously witnessed cardiac activity (prehospital or in-hospital).
   - Unresponsive hypotension (systolic blood pressure <70 mmHg) despite vigorous resuscitation.

2. Blunt thoracic injury with the following conditions:
   - Rapid exsanguinations from the chest tube (>1,500 mls immediately returned).
   - Unresponsive hypotension (SBP <70 mm Hg) despite vigorous resuscitation.†

B. Relative Indications

1. Penetrating thoracic injury with traumatic arrest without previously witnessed cardiac activity.
2. Penetrating non-thoracic injury (e.g. abdominal, peripheral) with traumatic arrest with previously witnessed cardiac activity (prehospital or in-hospital).
3. Blunt thoracic injuries with traumatic arrest with previously witnessed cardiac activity (prehospital or in-hospital).

C. Contraindications

1. Blunt injury without witnessed cardiac activity (prehospital)
2. Penetrating abdominal trauma without cardiac activity (prehospital)
3. Non-traumatic arrest
4. Severe head injury
5. Severe multisystem injury
6. Improperly trained team
7. Insufficient equipment

† Persistent post-injury hypotension due to: cardiac tamponade, intra-thoracic hemorrhage, or air embolism.

Table 4. Primary goals of emergency thoracotomy.[15 – 18]

1. The control of massive intra-thoracic or intra-abdominal hemorrhage
2. The release of cardiac tamponade
3. The internal or open cardiac massage
4. The prevention or control of air embolism
5. The control of bronchopleural fistulae
6. The cross-clamping of descending aorta in order to redistribute limited blood flow to the myocardium and brain and limit sub-diaphragmatic haemorrhage.

Techniques of emergency thoracotomy

The thoracotomy incision may be made on the lateral aspect of the chest, under the arm (axillary thoracotomy); on the anterior aspect, through the sternum (median sternotomy); slanting from the posterior to the lateral aspect of the chest (posterolateral thoracotomy); or under the breast (anterolateral thoracotomy). The exact location of the incision depends on the reason for the surgery.

In the case of an emergency thoracotomy, the procedure performed depends on the type and extent of injury. A supine anterolateral thoracotomy is most often the accepted approach.[19] A left sided approach is used in all patients in traumatic arrest and with injuries to the left chest (fig. 1). A right-sided approach may be used in non-arrested patients with right-sided injuries. The incision is typically made in the fourth intercostal space, beginning at the sternum and extending to the posterior axillary line. The skin is separated and the intercostal muscles are completely transected. Finally, a rib spreader is placed between the ribs to expose the intra-thoracic contents.

Although the anterolateral thoracotomy has the advantage of quick and simple access to the pericardium, exposure of the heart is limited and identification of the site of bleeding may be difficult for the non-specialist. Patients who are not arrested but with profound hypotension and right sided injuries have their right chest opened first. With a right sided thoracotomy, the left chest will have to be opened if internal cardiac massage becomes necessary. In both cases it may become necessary to extend the incision across the sternum to aid access and vision.

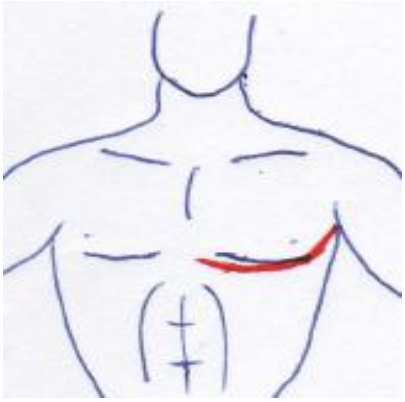


Figure 1: Left sided anterolateral thoracotomy

A bilateral approach to emergency thoracotomy that was originally developed for a doctor working single handed in the prehospital environment has been described.[20] It has been used successfully for many years, gives an extensive exposure of the heart and reliably rules out

tension pneumothorax. This approach to tension pneumothorax has the additional advantage that the thorocostomies are also the start of the "clam shell" thoracotomy.[20] Bilateral thoracotomy combined with transverse sternotomy results in the "clam shell" incision, the largest incision commonly used in thoracic surgery (Figure 2). A "clam shell" thoracotomy provides almost complete exposure to both thoracic cavities. In general, the indications for performing a 'clam shell" thoracotomy are when you need access to both sides of the chest, or just when you need better access than a unilateral thoracotomy can give you.[21]

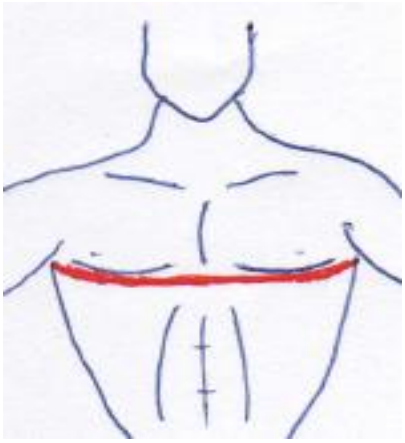


Figure 2: Bilateral thoracotomy

Prehospital emergency thoracotomy

If a patient sustains traumatic arrest in the prehospital setting, on scene immediate resuscitation is needed. Although there are guidelines for the emergency department,[11] guidelines on prehospital emergency thoracotomy are missing and, as a result, the decision to perform the procedure depends on the judgment of the doctor or on the policy of each medical service. In the trauma system of the London Helicopter Emergency Medical Service (HEMS) there is a policy to perform an on scene prehospital thoracotomy to a pulseless patient after penetrating thoracic injury especially if the nearest trauma centre is more than 10 minutes away (measured from loss of pulse to surgical intervention).[6] HEMS does not have a policy for patients with pulseless electrical activity.

Regardless of injury, performing a thoracotomy at the scene to a pulseless patient who has no cardiac activity is not a good idea; however, in penetrating injuries, it may have some role in a young person with a strong heart who exsanguinates. In a study by Athanasiou et al, of 39 patients that underwent thoracotomy at scene, 4 patients survived and 3 of these made a good neurological recovery.[6] According to these results, it seems that survival improves. This is consistent with the results of another study by Ahmad et al. who determined the frequency of survival in patients with thoracic trauma, undergoing urgent thoracotomy (survival of urgent thoracotomy was 84.7%).[9]

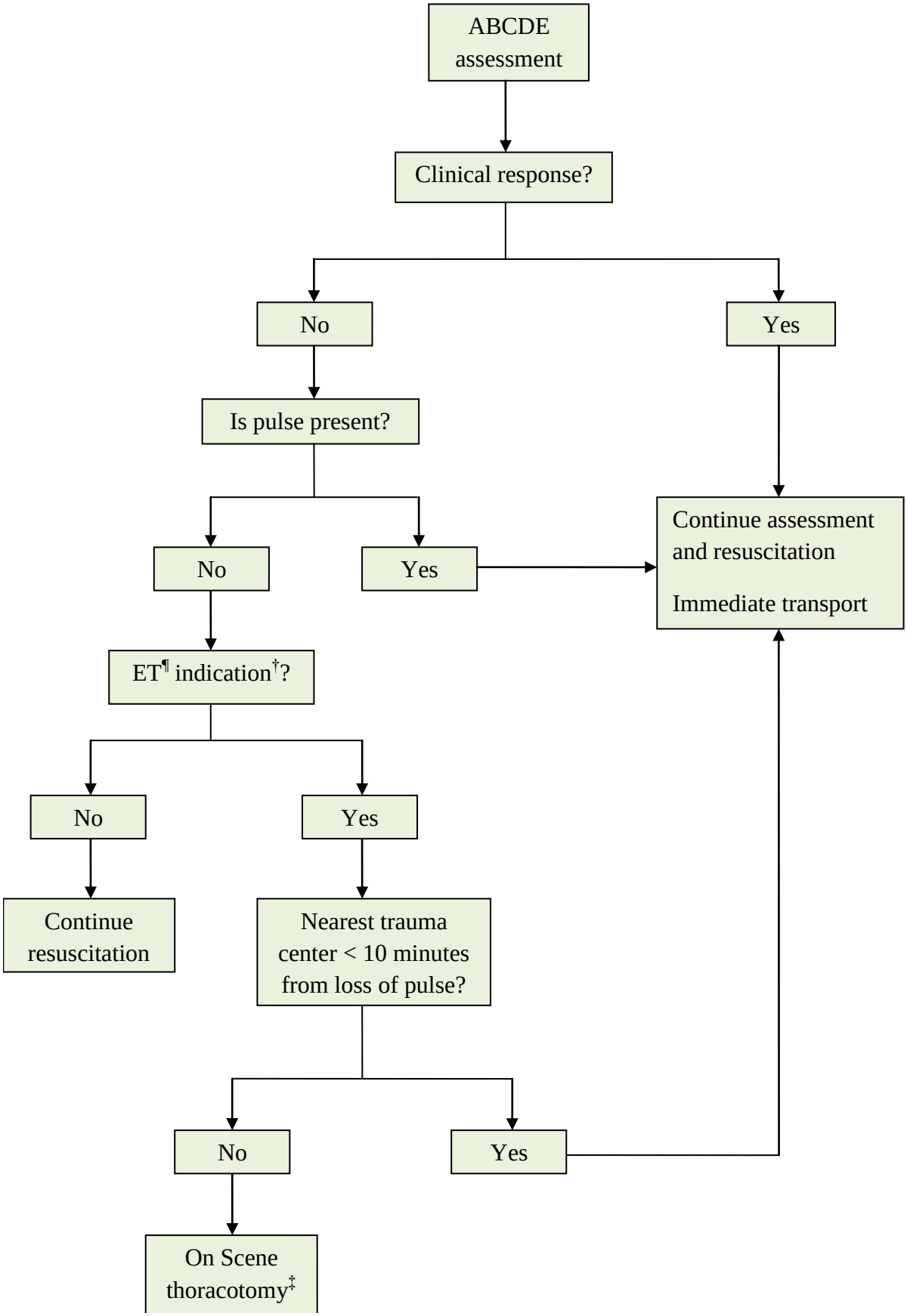
There are limited reports on the role of potential independent prehospital predictors on mortality after the performance of emergency thoracotomy.[7,8,22–24] Increased thoracotomy survival rates are associated with the presence of signs of life, with thoracic and penetrating injuries, and with stab wounds.[22] In one study, factors associated with survival were stab wounds, a single cardiac wound, cardiac tamponade, and the loss of pulse in the presence of an experienced prehospital doctor.[25] Another study demonstrated a statistically significant

improved survival rate when out of hospital emergency thoracotomy was performed in patients with penetrating rather than blunt trauma, and in patients with signs of life upon arrival of rescuers at the scene.[8] Stratification by mechanism of injury reveals a survival rate of 11.2% for penetrating trauma and 1.6% for blunt trauma.[11] The poor outcome from blunt trauma is consistent with the recommendation that emergency thoracotomy should rarely be performed in patients sustaining cardiopulmonary arrest from blunt trauma. Some authors consider thoracotomy to be futile in patients with blunt trauma requiring more than 5 minutes of prehospital cardiopulmonary resuscitation (CPR) and in patients with penetrating trauma requiring more than 15 minutes of CPR,[26] however others suggest that it may have a role.[10]

A successful outcome is possible if the patient has a cardiac tamponade and the definitive intervention is performed within 10 minutes of loss of cardiac output.[7,25,27] Unfortunately, there are no guidelines on prehospital emergency thoracotomy for patients being pulseless for a period of more than 10 minutes; nevertheless, according to one study, resuscitative thoracotomy has been reported as futile if out-of-hospital time has exceeded 30 minutes.[28] Although emergency thoracotomy can be the only way to resuscitate a patient who has suffered cardiac arrest, carrying out this type of procedure in the field is a cause for debate. Thus, based on current evidence,[6–8,11,27] a decision algorithm is proposed (Figure 3).

Trauma patients that respond to the initial assessment, or do not respond, but have a palpable pulse, should be rapidly transported to the hospital. Emergency thoracotomy should be considered in any patient who does not respond to the initial resuscitation, is pulseless and meets the criteria of Table 2. If the nearest trauma centre is more than 10 minutes away (measured from loss of pulse to surgical intervention), on scene thoracotomy should be performed. In case that emergency thoracotomy is not indicated, the resuscitative efforts should be continued as long as necessary.

Figure 3: Decision algorithm for prehospital emergency thoracotomy. [¶] Emergency thoracotomy. [†] As seen in Table 3. [‡] Perform emergency thoracotomy only if the patient is pulseless less than 10 minutes.



Discussion

Trauma still constitutes a significant cause of mortality and morbidity, and patients with severe trauma sustain severe pathophysiological derangement which worsens with time. In life-threatening conditions in which resuscitation is difficult, it is important to remember that the primary causes of traumatic arrest are hypoxia, hypovolaemia due to haemorrhage, tension pneumothorax, and cardiac tamponade.[29] Although hypoxic cardiac arrests respond rapidly to intubation and ventilation, control of bleeding and aggressive fluid administration may be inadequate or ineffective, respectively.[29] In such cases, invasive procedures may be required.

The risk to benefit ratio, and the ethics of emergency thoracotomy have been the subject of in-depth analysis in the literature. Many reports focus on the cost of the procedure and the low rate of survival, while others believe that no cost is too high to pay for saving a life.[30–33] Trauma resuscitations consume significant amounts of resources; it has been estimated that the expenditure for a successful thoracotomy is $93,000 but this could be reduced to $20,137 if thoracotomy is limited to selected patients.[32] It should also be noted that the performance of the thoracotomy procedure affords a greater potential for exposure to lethal infection.[31]

Although specific guidelines are lacking, when faced with no alternative, prehospital emergency thoracotomy can be a lifesaving procedure.[34] Time spent on the scene should not be considered as being 'wasted', but instead should be 'maximized' to provide the right care at the right time.[20] According to the London HEMS system, a prehospital thoracotomy is recommended if the nearest trauma centre is more than 10 minutes away (measured from loss of pulse to surgical intervention) from loss of pulse.[6] Patients that suffer a cardiac arrest more than 10 minutes away from emergency room thoracotomy are very unlikely to survive.[25] Nevertheless, a review of data from 24 studies demonstrated an overall survival of 7.4%.[35] In patients that did not undergo emergency thoracotomy (control), the probability of survival was extremely low. Despite the general morbidity of the procedure, the overall survival rate of 7.4% demonstrates the efficacy of emergency thoracotomy in selective situations, while the reported normal neurologic function in 92.4% of these patients indicates the usefulness of this procedure.[35]

In the study by Athanasiou et al. most of the emergency thoracotomies (37–70%) were performed by non-surgeons (anaesthetists and emergency consultants). Five of the patients survived (13.5%), which was not significantly different to the survival rate when the thoracotomy was performed by surgeons 5/16 (31.2%) (P=0.14).[6] It seems apparent that the doctor who is going to perform the procedure does not be necessarily need to be a surgeon, and that only a moderate knowledge of the anatomy of the area and the sequence of steps to be followed are needed.[20] However, the doctor must be sufficiently trained in performing the technique competently, as thoracotomy performed by untrained staff is futile, time consuming and may be harmful for the patients (although if they are in a traumatic cardiac arrest they are deceased already). A 'prehospital thoracotomy pack' which contains a small number of instruments that are easy to use should be available,[6] with a back-up pack, should the need arise.

While there is little evidence to support the use of one technique over another, a bilateral approach has some advantages.[5] Using this technique a non-cardiothoracic surgeon should be able to access the pericardium in 2–3 minutes. This approach provides excellent exposure of the heart and lower mediastinum, and can be performed on the supine patient. It also provides access to both pleural cavities and allows the operator to view the anatomy from the front, making orientation easy.

Conclusion

On-scene emergency thoracotomy may be a lifesaving procedure when performed with the correct indications and approaches, especially in selected patients. The proposed algorithm can serve as a guide to help physicians decide when to perform the procedure. However, further education, research, and protocol development are required to improve the outcome of patients that undergo prehospital emergency thoracotomy, and presumably, the need to undertake the intervention in trauma patients.

Author(s): Athanasios F. Chalkias

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