Is Emergency Department Thoracotomy Effective in Trauma Resuscitation? The Retrospective Study of the Emergency Department Thoracotomy in Trauma Patients at Thammasat University Hospital, Thailand

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Introduction: The survival rate after the emergency department thoracotomy (EDT) in trauma patients varies from the previous study as 1.6% in blunt injury and 11.2% in penetrating injury. Most of the data came from Europe, the US, South Africa, and Japan. This study aims to identify the success of EDT in trauma patients at Thammasat University Hospital, Thailand, and to evaluate the effectiveness of EDT. This study may be representative data for Southeast Asia. Materials and Methods: This retrospective review of 21 consecutive EDT cases which performed by our staffs and chief of general surgery residents between June 2009 and July 2016. Age, gender, injury mechanisms, injury sites, patient transport methods, initial vital signs, fluids and blood component requirements, resuscitation times, laboratory results, and injury severity scores were all analyzed. Results: Of the 21 EDT cases, one patient was excluded due to being a nontraumatic case. The remaining twenty patients were primarily young (mean 36.5 years), male (85%), suffering from blunt injuries (75%), of which 45% were predominantly thoracic injuries. Most of the patients presented without any sign of life (75%), and the total time for resuscitation was 43.5 ± 19.6 min. Seven patients (35%) had the return of spontaneous circulation (ROSC) and were successful in being brought to the operating room. Unfortunately, all patients passed away within 24 h of the operation. Conclusions: The ROSC rate of EDT in this study was 35%, but with no survival benefit. Therefore, we cannot guarantee that EDT serves as an effective life-saving procedure. However, EDT may play a significant role in treating extremis injured patients.

Keywords: Emergency department thoracotomy, emergency room thoracotomy, resuscitative thoracotomy, trauma

Introduction
Emergency thoracotomy has been used as a treatment of anesthetic-related cardiac arrest in the early 1900s, but with limited data on trauma patients until the early 1960s.[1] The first reported successful case of emergency department thoracotomy (EDT) was from Dr. Rehn who performed EDT on a dying patient with a stab wound to the heart.[2] In the 1960s, immediate thoracotomy was used to salvage patients suffering from life-threatening chest wounds.[3] However, since the early 1960s, EDT has been performed worldwide for serious, life-threatening injuries. Current indications for EDT include salvageable postcardiac arrest in penetrating thoracic and nonthoracic injuries, blunt torso injuries, and postinjury persistent hypotension.[4] Most current EDT data have been obtained from Europe, the USA, South Africa, and Japan.[5-9] Rationales for performing EDT include (1) releasing traumatic cardiac tamponade by pericardiotomy and the evacuation of blood clots and/or repair of cardiac injuries, (2) increasing cardiac output by internal cardiac massage and/or internal cardiac defibrillation, (3) controlling intrathoracic hemorrhage by pulmonary hilar control and/or repair of the pulmonary
wound, (4) decreasing intra-abdominal hemorrhage and the redistribution of the remaining blood volume by thoracic aortic cross-clamping, and (5) evacuating bronchovenous air embolisms.[10]

The success in EDT varies according to different studies. In 2000, Rhee et al. reviewed 25 years’ experience of EDT in 24 studies involving 4620 cases.[19] According to the results, the survival rate after EDT was 7.4%, with the highest survival in penetration injury patients (8.8%), especially those with stab wounds. Patients with signs of life (SOL) on arrival had a significantly higher survival rate compared to patients without SOL on arrival (11.5% vs. 1.2%). The American College of Surgeons Committee on Trauma (ACSCOT) guidelines were established in 2001.[11] The guidelines reviewed 7035 EDT cases performed between 1966 and 1999. The overall survival rate in penetration injury patients was 11.2% compared to 1.6% with blunt injury patients. In these guidelines, it was recommended that EDT be performed on penetration injury patients with SOL and short transport times; but for blunt injury patients, only witnessed cardiac arrest cases were recommended.

Specifically focusing on mechanism bases, a study by Fairfax et al. reviewed studies on EDT with penetration injuries between 1999 and 2012, involving 1384 cases. In this study, the survival rate after EDT by penetrating mechanisms was 9.8%. This study suggested that performing EDT in cases of penetration trauma with a witnessed cardiac arrest, particularly if the patient had developed cardiac tamponade from a single cardiac wound. But if the patient had multiple injuries or no SOL at the scene, EDT was not recommended.[10] A study from Khorsandi and Skouras reviewed 25 years’ experience of EDT in 24 trauma patients without SOL at the scene, vital signs with <15 min of CPR in patients with penetration wounds to the torso, persistent hypotension in trauma patients suspected with cardiac tamponade, air embolism, or massive intra-thoracic or abdominal–pelvic bleeding without response to initial fluid resuscitation. The contraindications for this procedure included trauma patients without SOL at the scene, unknown injury durations, and nondetectable vital signs of more than 15 min of CPR in a patient with a penetrating wound to the torso or >10 min of CPR in a patient with a blunt torso wound.

For this study, we aimed to identify the success of EDT at Thammasat University Hospital (TUH), Thailand, a Level I trauma center in the South-Central region of Thailand, and thereby identify the factors that displayed a significant association with successful EDT in our institute. These data represented the effectiveness of EDT for trauma resuscitation in our institute, and this may also be considered representative data for Southeast Asia.

**Research registry**

This retrospective study was registered to ResearchRegistry.com, and the unique identifying number was research registry 4585.

**Ethics**

This retrospective study was performed at TUH. This project was approved by the Human Ethics Committee of Thammasat University No. 1 (Faculty of Medicine), Thailand (MTU-EC-SU-0-081/59) and waived the requirement for informed consent due to the retrospective nature of the study.

**Materials and Methods**

This is a single-institute retrospective review of EDT cases. A total of 21 cases of EDT involving trauma patients from June 2009 to July 2016 were reviewed. Patient variables included age, sex, mechanism of injury, vital signs at the scene, vital signs on arrival, transport times and methods, the regional Abbreviated Injury Scale (AIS), the Injury Severity Score (ISS), laboratory parameters, cardiopulmonary resuscitation (CPR) times, time intervals between arrival and the performing of EDT, procedure times, operators, resuscitation fluids and blood transfusions, anesthesia records, and the results (return of spontaneous circulation [ROSC] or death) were collected and analyzed.

EDT in our institute defined as an emergency thoracotomy performed at an emergency department to revive the patient’s life. This procedure will be performed by the general surgical staff or the chief of general surgery resident who on duty at that time. If the patient shows the ROSC, the patient will be transferred to the operating room (OR) for damage control surgery. If the patient can survive the operation, the patient will be transferred to the intensive care unit (ICU) for the further resuscitation and brought back to the OR for the definitive surgery in the next 48–72 h.

ROSC is defined as one or more of the following features: the presence of blood pressure, spontaneous respiration or motor response, and the presence of cardiac electrical activity with pupillary response. The indications for EDT at TUH included witnessed traumatic cardiac arrest (by any mechanism), nondetectable vital signs with <15 min of the CPR in patients with penetration wounds to the torso, <10 min of CPR in patients with blunt torso wounds, and persistent hypotension in trauma patients suspected with cardiac tamponade, air embolism, or massive intrathoracic or abdominal–pelvic bleeding without response to initial fluid resuscitation. The contraindications for this procedure included trauma patients without SOL at the scene, unknown injury durations, and nondetectable vital signs of more than 15 min of CPR in a patient with a penetrating wound to the torso or >10 min of CPR in a patient with a blunt torso wound.

All of the EDT cases were separated into two groups: ROSC and non-ROSC group, and we tried to define the difference between these groups to identify which factors that contributed to the success of EDT (ROSC). This study has no potential sources of bias.

**Statistics**

The statistical analysis tools used were IBM® and SPSS® Version 20 for Windows® (SPSS, Chicago, Illinois, USA). Values were reported as percentages for categorical variables and means (range) for continuous variables. Comparison data, such as demographic and clinical characteristics, were evaluated using bivariable analysis. Independent risk factors associated with ROSC following EDT were measured using
a stepwise logistic regression method. Statistical significance was set at \( P < 0.050 \).

**Results**

During the 7-year study interval, 21 cases underwent EDT. One patient was excluded due to being a nontraumatic case (this patient was initially diagnosed with a witnessed cardiac arrest associated with a history of a fall but was diagnosed definitively with a ruptured abdominal aortic aneurysm); only twenty traumatic cases were included to this study. The mean age was 36.5 years (15–65). Most of the patients were male (85%). Fifteen patients (75%) had sustained blunt torso injuries, four patients (20%) had a stab wound to the torso, and only one patient (5%) had suffered a gunshot wound to the abdomen. Nine patients (45%) were deemed to be predominately chest injuries (chest AIS \( \geq 3 \)) without severe abdominal injuries (abdominal AIS \( \geq 2 \)), seven patients (35%) were combined chest (chest AIS \( \geq 3 \)) and abdominal injuries (abdominal AIS \( \geq 3 \)), and four patients (20%) were combined torso with severe extremity (extremity AIS \( \geq 3 \)) or face and neck injuries (face or neck AIS \( \geq 3 \)). Only three patients (15%) displayed clear evidence of severe head injuries (head AIS \( \geq 3 \)) on arrival. Most of the patients (75%) presented to the emergency room were without SOL. Only five patients (25%) had SOL and collapsed during the resuscitation process. In this group, the mean SBP was 99 mmHg (46–186). Most of the patients (70%) had been transported to the emergency room by their friends, families, or through foundation emergency services. Only six patients (30%) were transferred to the emergency room by qualified paramedics through emergency medical services. The average prehospital fluid administration was 1.6 ± 0.5 L (1.0–2.5). All of the patients had their blood loss estimated at the scene with the average blood loss at the scene being 2.2 ± 0.6 L (1.0–3.0). The mean ISS was 40 (25–55). All patients had initial blood collection for laboratory evaluation on arrival at the emergency room. The mean hematocrit was 29.4 ± 12.2 g/L (4.5–46.5). The mean hemoglobin was 10.0 ± 3.7 g/dL (1.6–15.1). The average platelet count was 143,400 ± 88,206/cu. mm (5,000–283,000). The mean arterial pH was 6.93 ± 0.16 (6.80–7.30). The average INR was 1.81 ± 0.52 (1.00–2.70). The mean serum sodium level was 139.5 ± 3.9 mmol/L (132–149). The mean serum potassium level was 4.2 ± 0.9 mmol/L (3.0–7.0). The average bicarbonate level was 17.0 ± 5.4 mmol/L (4.0–27.3). The demographics, injury characteristics, prehospital and arrival data, and initial laboratory results of all patients are presented in Table 1. Bivariate analysis was used to define the correlation of factors between two groups: ROSC after EDT and non-ROSC after EDT, for which \( P \) values are reported.

All patients received closed-chest CPR, followed by EDT. For most patients (70%), EDT was performed by a surgical resident, with six patients being performed on by general surgical staff. The mean crystalloid fluid resuscitation volume was 2.74 ± 1.2 L per patient (1.5–6.0). The total pack red cell for resuscitation was 3.25 ± 2.4 units per patient (0–6), and the total fresh frozen plasma was 1.00 ± 1.7 unit per patient (0–4). The average CPR time (closed-chest CPR and EDT) was 43.5 ± 19.6 min (23–65). Seven patients (35%) had ROSC after EDT and therefore were considered able to be brought to the operation room for damage control surgical treatment. The resuscitation data of patients are shown in Table 2.

In the ROSC group, the average time from the start of CPR to the start of operation was 29 ± 22.4 min. Two patients had predominately blunt chest injuries without severe abdominal injury, one case included massive bleeding from the lung hilar with a severe bilateral lung contusion (noted after an extended incision to the Clamshell thoracotomy), and another case included a massive hemotorax with a thoracic aorta injury. Five patients had mainly abdominopelvic injuries, one case was a multiple thoracoabdominal stab wound with lung, liver, IVC, and bowel injuries, and the five other cases were blunt abdominopelvic injuries. Five patients died on the table. Only two patients (10%) survived damage control surgery and were brought to ICU for the resuscitation phase. Unfortunately, all patients passed away within 24 h of the surgery. The details of the injuries are described in Table 3.

From this data, we noted some common significant factors (\( P < 0.050 \)) between the ROSC group and the non-ROSC group [as displayed in Tables 2 and 3]. We found that prehospital blood loss, initial hematocrit, hemoglobin level, platelet count, and arterial pH were significantly different between the two groups. Other factors that may signify differences such as age (we performed a subgroup analysis for those aged <60 years and found \( P = 0.186 \)) and total resuscitation time (we performed a subgroup analysis for those with a total resuscitate time of <30 min and found \( P = 0.066 \)) were calculated using a stepwise logistic regression analysis to identify independent risk factors, with the results shown in Table 4.

The independent variables that were associated with ROSC after EDT in all age groups were increased prehospital blood loss and decreased hematocrit levels (especially Hct <30 g%), hemoglobin levels (especially Hb <10 g/dL), and platelet counts. We attempted to analyze these variables by performing a multivariate analysis; but, unfortunately, this failed to reveal any predictors of success in EDT.

**Discussion**

In the majority of the previously reviewed literature, most of the patients were suffering from penetration injuries;\(^{[5,31]}\) but in our study, most of the patients had blunt injuries (75%). According to our study, patients with blunt mechanisms had a higher rate of ROSC after EDT (40%) compared to patients with penetrating mechanisms (25%) and a zero ROSC rate for the single patient with a gunshot mechanism. Our result may be different from the previous studies due to the fact that the location of our center is close to a major highway, and most of our patients were motor vehicle accident victims, hence the most common mechanism being blunt injury. Regardless,
according to our study, blunt mechanism was not associated with ROSC after EDT (P = 0.444). As for penetrating trauma, according to our study, this factor was also unrelated to ROSC after EDT (P = 0.660).

Most of our patients had no SOL at ER before starting EDT. Only 25% of patients had any SOL, and this factor was not associated with ROSC after EDT in our study (P = 0.444), in contrast to previous studies, where the presence of SOL was significantly associated with ROSC after EDT. This result indicates that our patients may have been more severely injured or may have suffered from poor quality prehospital care. Furthermore, the more severe nature of our patients’ injuries may explain why none of the ROSC after EDT patients in our study could survive until discharge.

Many previous investigators have found that the location of the injury, especially chest injuries, was associated with successful EDT. The most successful location was cardiac injuries, especially a single cardiac penetrating wound, and the least successful was multiple injuries, especially blunt mechanisms. Another injury location, in this case severe head injuries, was examined in a study by Lustenberger et al., in which a Glasgow Coma Scale of <8 was related to unsuccessful EDT. In our study, the location of injury was not related to ROSC after EDT (P = 0.893).

### Table 1: Demographics, injury characteristics, initial clinical data, and initial laboratory results of patients

|                          | Total (n=20) | ROSC (n=7) | Non-ROSC (n=13) | P    |
|--------------------------|-------------|-----------|-----------------|------|
| Demographics             |             |           |                 |      |
| Age (years)              | 36.5 (15-65)| 36.1      | 36.7            | 0.934|
| Gender (male %)          | 85          | 100       | 76              | 0.186|
| Injury mechanism (n)     |             |           |                 |      |
| Blunt torso              | 15          | 6         | 9               | 0.444|
| Penetrating torso        | 4           | 1         | 3               | 0.660|
| Gunshot torso            | 1           | 0         | 1               | 0.478|
| Specific mechanism (n)   |             |           |                 |      |
| Chest injury (Abd AIS ≤2)| 9           | 2         | 7               | 0.895|
| Head AIS ≥3              | 3           | 0         | 3               | 0.082|
| Prehospital and arrival data |         |           |                 |      |
| Presence of SOL (%)      | 25          | 14        | 30              | 0.444|
| Prehospital blood loss (L)| 2.2 (1.0-3.0)| 2.6      | 2.0             | 0.031|
| Received prehospital fluid (n) | 6 | 1 | 5 | 0.245 |
| Mode of transfer         |             |           |                 |      |
| EMS: Non-EMS (%)         | 30:70       | 14:86     | 38:62           | 0.245|
| ISS                      | 40 (25-55)  | 42        | 39              | 0.320|
| Initial laboratory results|             |           |                 |      |
| Hct (g %)                | 29.4 (4.5-46.5)| 20.9 | 33.9           | 0.018|
| Hb (g/dL)                | 10.0 (1.6-15.1)| 6.6     | 11.8           | 0.011|
| Platelet count (*10^3 cells/cu.mm) | 143.4 (5-283)| 83.8 | 175.4          | 0.022|
| Arterial pH              | 6.93 (6.8-7.3)| 6.82    | 6.98           | 0.014|
| Na (mmol/L)              | 139.5 (132-149)| 139.5 | 139.5         | 0.986|
| K (mmol/L)               | 4.2 (3.0-7.0)| 4.2      | 4.2            | 0.886|
| HCO3 (mmol/L)            | 17.0 (4.0-27.3)| 16.0   | 17.6          | 0.546|
| INR                      | 1.81 (1.00-2.70)| 1.92   | 1.75          | 0.496|

ROSC: Return of spontaneous circulation, AIS: The Abbreviated Injury Scale, SOL: Signs of life, EMS: Emergency medical service, Abd: Abdomen, Hct: Hematocrit, Hb: Hemoglobin, Na: Serum sodium, K: Serum potassium, HCO3: Serum bicarbonate, INR: International normalized ratio, ISS: Injury severity score

### Table 2: Resuscitation data of patients

|                          | Total (n=20) | ROSC (n=7) | Non-ROSC (n=13) | P    |
|--------------------------|-------------|-----------|-----------------|------|
| Operator (n)             |             |           |                 |      |
| Surgical resident:staff  | 14:6        | 4:3       | 10:3            | 0.420|
| Resuscitation data       |             |           |                 |      |
| Crystalloid fluid (L/case)| 2.70 (1.5-6.0)| 2.50 | 2.83           | 0.587|
| PRC (units/case)         | 3.2 (0-6)   | 2.6       | 3.6             | 0.385|
| FFP (units/case)         | 1.0 (0-4)   | 1.2       | 0.9             | 0.790|
| Total resuscitation time (min/case) | 43.5 (23-65)| 42.4 | 44.2          | 0.857|

ROSC: Return of spontaneous circulation, PRC: Pack red cell, FFP: Fresh-frozen plasma
Using this data, we found that it was too difficult to define factors that contributed to ROSC after EDT, perhaps due to the small sample size. However, regarding prehospital and in-hospital data, we did find some significant relationships to ROSC after EDT. Prominent among these were prehospital blood loss, in-hospital laboratory data, especially bleeding parameters such as Hct, hemoglobin, platelet counts, and arterial pH may relate to ROSC after EDT. The trend of these parameters indicated a relationship between the amount of bleeding and ROSC that may contribute the benefit of EDT in the extremis injured patient. The correlation may be due to the severity of the injuries, or the fact that our team was very active in resuscitating in extremis patients, although perhaps this should be investigated further. Other prehospital and in-hospital resuscitation data in this study indicated no significant differences between ROSC and non-ROSC after EDT. Furthermore, as with the previous literature, no conclusions can be made about prehospital and in-hospital mortality predictability factors.[5,8,9,11-15]

The ROSC after EDT rate in our study was 35%. However, a 0% survival rate would be the result. We believe that too many other factors contributed to the survival of trauma patients besides EDT. We decided to define ROSC after EDT as successful EDT because this stage strongly associated with EDT procedures that may reduce other confounding factors.

As an extremis injured patient because this process could increase the chance to bring the patient to the next step of care. We would be increased the survival after EDT if we improved the quality of other parts for the extremis injured patient care such as damage control surgery, ICU facility, and knowledge.

**Conclusions**

In our study, the ROSC after EDT rate was 35%, but with no survival benefits. Therefore, it cannot be established that EDT is an effective life-saving procedure. However, our results indicate that EDT may play a role in treating extremis injured patients and increase the chance to bring the patient to the appropriated next step of treatment that may improve survival. Due to the small sample size, a more sizeable prospective study may be required in the future.

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Nil.

**Conflicts of interest**

Kanlerd A, Sapsamarn N and Auksornchart K have no conflict of interests.

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### Table 3: Detail of injuries in return of spontaneous circulation group (n=7)

| Case | Detail of Injuries |
|------|-------------------|
| 1    | Blunt chest injury: Massive right hemothorax, bleeding from right pulmonary hilum and severe bilateral lung contusion, multiple ribs fracture, and cardiac contusion with hemopericardium |
| 2    | Blunt chest injury: Massive left hemothorax, descending thoracic aorta injury, cardiac contusion with hemopericardium, left lung contusion, multiple ribs fracture |
| 3*   | Multiple thoracoabdominal stab wounds: Stab wound to the right lung with hemothorax, multiple liver stab wounds with massive bleeding from the retrohepatic area, right diaphragmatic injury, infrarenal IVC injury, right kidney injury, multiple stab wounds at the colon, small bowel, and mesentery |
| 4*   | Blunt abdominopelvic injury: Liver laceration, splenic laceration, mesenteric contusion and small bowel perforation, bladder rupture, and pelvic fracture with retroperitoneal hematoma |
| 5    | Blunt abdominopelvic injury: Unstable pelvic fracture with severe pelvic organ injury, bilateral iliac artery and vein injury |
| 6    | Blunt abdominal injury: Liver laceration at hilar, splenic laceration, severe pancreatoduodenal injury and IVC injury |
| 7    | Blunt abdominal injury: Liver laceration, stomach rupture, splenic laceration, expand mesenteric root hematoma from the root of SMA and celiac artery, multiple small bowel contusion, and left kidney injury |

*This case was a successful DCS but the patient died in the ICU phase. IVC: Inferior vena cava, SMA: Superior mesenteric artery, DCS: Damage control surgery, ICU: Intensive care unit

### Table 4: Logistic regression analysis of the association between return of spontaneous circulation after emergency department thoracotomy and significant clinical variables (adjusted age at <60 years)

| Variable                      | Crude   | Age adjusted |
|-------------------------------|---------|--------------|
| Age (years)                   | 0.930 (0.938-1.060) | 0.236 (0.965-1.156) |
| Prehospital blood loss (L)    | 0.049 (1.014-89.960) | 0.045 (1.062-116.337) |
| Hct (g/dL)                    | 0.038 (0.821-0.994) | 0.049 (0.809-1.000) |
| Subgroup: Hct <30 g %         | 0.021 (0.008-0.674) | 0.021 (0.003-0.621) |
| Subgroup: Hb <10 g/dL         | 0.025 (0.329-0.927) | 0.074 (0.137-0.998) |
| Platelet count (<10¹² cells/cu.mm) | 0.021 (0.008-0.674) | 0.021 (0.003-0.621) |
| Arterial pH                   | 0.079 (0.001-3.008) | 0.088 (0.001-3.824) |
| Total resuscitation time (min/case) | 0.847 (0.948-1.045) | 0.995 (0.953-1.047) |
| Subgroup: Total resuscitation time <30 min | 0.089 (0.717-113.016) | 0.142 (0.526-86.561) |

Hct: Hematocrit, Hb: Hemoglobin

This may be due to the small sample size, but even though we performed a subgroup analysis of those with predominantly chest injuries, patients had always sustained multiple injuries in cases involving blunt mechanisms. In our study, those patients with severe head injuries were also unrelated to ROSC after EDT (P = 0.082).
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