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ORIGINAL RESEARCH

Predictors of survival after emergency department thoracotomy in trauma patients with predominant thoracic injuries in Southern Israel: a retrospective survey

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Yael Refaely[1,*]
Leonid Koyfman[2,*]
Michael Friger[3]
Leonid Ruderman[1]
Mahmud Abu Saleh[1]
Moti Klein[2]
Evgeni Brotfain[2]

[1]Department of Cardiothoracic Surgery, Soroka Medical Center, Ben-Gurion University of the Negev, Beer Sheva, Israel; [2]Department of Anesthesiology and Critical Care, General Intensive Care Unit, Soroka Medical Center, Ben-Gurion University of the Negev, Beer Sheva, Israel; [3]Department of Public Health, Faculty of Health Sciences, Ben-Gurion University of the Negev, Beer Sheva, Israel

*These authors contributed equally to this work

Introduction: Emergency department thoracotomy (EDT), also termed "resuscitative thoracotomy", is indicated in some cases of life-threatening isolated thoracic injury, or as a part of CPR (cardiopulmonary resuscitation) in multiple trauma patients, or in thoracic trauma patients with massive bleeding (such as intra-abdominal exsanguination or injury to the great vessels). There is a lack of information in the literature concerning predictors of survival after EDT in patients with predominant or isolated thoracic trauma.

Patients and methods: The study was retrospective and single-center. We collected clinical and laboratory data from all civil and military trauma patients admitted to our emergency department (ED) with predominant thoracic injuries who underwent EDT at Soroka Medical Center. A total of 31 patients were included in the study.

Results: Of the patients in the study group, 58% presented with penetrating thoracic injuries and 42% presented with blunt thoracic injuries. 13 patients (42%) survived the EDT procedure. The following parameters predicted survival after EDT: signs of life and the presence of sinus rhythm on admission to the ED; heart rate at the end of the EDT procedure; short duration of EDT; and total positive balance (fluid and blood products) after EDT. Patients who sustained penetrating stab wound injuries had a better immediate post-operative survival rate after EDT than those who sustained penetrating gunshot wounds or predominant blunt chest trauma (30.8% vs 11.1%; p-0.034). Six patients (19%) survived until discharge from the hospital: 3 with penetrating injuries and 3 with blunt thoracic injuries.

Conclusion: In patients undergoing EDT after thoracic injury we found that the clinical status on admission to the ED, the duration of the EDT procedure and the heart rate at the end of procedure were predictors of survival after EDT. We demonstrated a higher survival rate after EDT in patients with predominant penetrating thoracic trauma.

Keywords: emergency department thoracotomy (EDT), blunt chest trauma, penetrating chest trauma

Introduction

Thoracic trauma is an important cause of morbidity and mortality throughout the world.[1] It occurs in more than 50% of cases of multiple trauma and is associated with a high mortality rate (~25%).[1,2] The majority of chest trauma patients can be managed conservatively with chest tube drainage only.[3] However, a small minority require emergency department thoracotomy (EDT), also termed

Correspondence: Evgeni Brotfain
Department of Anesthesiology and Critical Care, Soroka Medical Center, Ben Gurion University of the Negev, Beer Sheva 84101, Israel
Tel +97 254 621 8106
Email bem1975@gmail.com

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"resuscitative thoracotomy". This procedure is indicated in cases of isolated life-threatening thoracic injury, or as a part of CPR (cardiopulmonary resuscitation) in multiple trauma patients, or in thoracic trauma patients with massive bleeding from other injuries (such as intra-abdominal exsanguination or injury to the great vessels).[4,5] The overall survival rate after EDT reported by the American College of Surgeons Committee on Trauma is 15–21%.[1–8] The highest survival rate (15%) was observed after penetrating injuries while the lowest rate (2.4%) was observed after blunt trauma.[1,9] Knowledge of the predictors for survival of critically ill patients with blunt and penetrating thoracic injuries who undergo EDT might contribute to improving outcomes in these patients. Mortality after EDT in multiple trauma patients has been shown to correlate strongly with the presence of a number of clinical signs observed both at the scene of the trauma and on admission to the ED; with the location of the anatomic injury; and with a number of laboratory parameters.[10] Although most patients with thoracic injury do not require EDT, there remains a small but significant subgroup of patients (10–15%) with predominant or isolated thoracic trauma who do require emergency thoracotomy. However, there is a lack information regarding the predictors of survival after EDT in these patients. In this study, carried out at the Soroka Medical Center, a Trauma Level I Medical Center with extensive experience in civil and military trauma, we retrospectively analyzed clinical data from the last decade with the aim of discovering the predictive factors for survival after resuscitative thoracotomy in patients with predominant thoracic trauma.

Patients and methods

Soroka Medical Center, is a 1000-bed tertiary-care, Trauma Level I, university teaching hospital located in Beer Sheva in southern Israel, The study was retrospective and single-center. The Human Research and Ethics Committee at Soroka Medical Center approved the study (RN-0124–15-SOR). The Human Research and Ethics Committee at Soroka Medical Center waived the need for informed consent. The patient data was either anonymized or treated with confidentiality, in accordance with the Declaration of Helsinki.

We collected clinical and laboratory data from all civil and military patients with predominant thoracic trauma who underwent EDT at Soroka Medical Center between January 2005 and June 2015.

Inclusion criteria

All thoracic trauma patients, aged ≥18 who had predominant blunt and/or penetrating chest injury on admission to the ED and who underwent resuscitative EDT at the Soroka Medical Center between January 2005 and June 2015 were included in the study. Patients were considered to have survived if they were alive when discharged from the trauma center or transferred to a rehabilitation service. The decision to perform EDT was based on the American College of Surgeons Committee on Trauma practice guidelines (A practice management guideline from the Eastern Association for the Surgery of Trauma.[1] EDT was carried out at the discretion of a trauma specialist or a senior trauma resident, and was performed through a left anterolateral thoracotomy, on all patients who presented with penetrating or blunt thoracic injury accompanied by pulseless electrical activity (PEA) or a pulse rate of <40 beats/min and/or signs of life (detection of pulse, spontaneous breathing and verbal response) an admission to the ED.

Exclusion criteria

Multiple trauma patients with severe injuries to other body parts (head, abdomen, extremities) and no documented blunt or penetrating chest injury on admission to the ED were excluded from the study.

Variables and measurements

We collected data from the patients' EMS (emergency medical services) records, their hospital and ICU (intensive care unit) electronic records (including demographic data, underlying co-morbidities; time elapsed between admission to the ED and performance of EDT; duration of the EDT procedure; clinical and therapeutic data in ED and during ICU stay. The following data from the patients' ED stay were also recorded: intraoperative blood loss volume, intraoperative findings; RTS (Revised Trauma Score); ISS (Injury Severity Score)), and their laboratory data base.

Scores

The RTS and the ISS (an anatomical scoring system used for evaluation of all trauma patients on admission to the ED at Soroka Medical Center) were used for evaluation of trauma severity on admission to the ER. Severity of critical illness and degree of multi-organ failure were evaluated using the APACHE II (Acute Physiology and

Chronic Health Evaluation II) score for each patient who was hospitalized in the General and Cardiothoracic ICUs.

Statistical analysis

For categorical variables, proportions were compared using Fisher's Exact Test or Chi Square as appropriate. Continuous variables were analyzed with a Student's *t*-test or the Wilcoxon Rank Sum Test, depending on the validity of the normality assumption. For comparison of minute-to-minute urine rate variability the coefficient of variation was calculated and analyzed with a Student's *t*-test. A two-tailed *p*-value of <0.05 was considered to be significant. All analyses were performed using SPSS version 22.

Results

We analyzed the clinical and laboratory data of 40 civilian and military trauma patients with predominant thoracic injuries who were admitted to the ED and who underwent EDT between January 2005 and June 2015. Of these, a total of 31 patients were included in the study (the remaining 9 patients were excluded on the base of incomplete data in their medical records). The demographic data, mechanisms of injury and clinical characteristics of the study patients are summarized in Table 1. The patients were predominantly young adult males. (Table 1). Overall, 58% of the patients presented with penetrating thoracic trauma (stab and gunshot wounds) and 42% presented with blunt thoracic trauma (Table 1). Most of the patients (93.5%) had signs of life at the scene of the injury but only half (48.4%) had signs of life on admission to the ED (Table1). Most of the patients (62%) underwent CPR at the scene of the injury. Sinus rhythm was present in 42% of the patients on admission to the ED.

The GCS (Glasgow Coma Score) at the scene of the injury was 7.3±2.6 and was significantly less (5.54±1.9) on admission to the ED. Thirteen patients (42%) survived the EDT procedure; they were then transferred to the operating room (OR) and thereafter to the general or cardiothoracic ICU (Table 1).

Table 2 shows the results of univariate analysis of the predictors of survival after EDT in trauma patients with predominant thoracic injuries. The following parameters were predictors of survival after EDT in this study population (Table 2): signs of life and sinus rhythm on admission to the ED; heart rate above 80 per min at the end of the EDT procedure; short duration of EDT; amount of packed

Table 1 Overall demographics and clinical characteristics

Total	n=31
Demographic data	
Age, years (mean±SD)	32.29±13.82
Male gender n (%)	27 (87)
Weight (kg, mean±SD)	76.39±15.75
Mechanism of injury[a] (%)	
Stab wound	6 (19.3)
Gunshot wound	12 (38.7)
Blunt trauma	13 (42)
Injury scores	
Revised trauma score (RTS) (units, mean ± SD)	7.35±2.21
Injury severity score (ISS) (units, mean ± SD)	38.35±13.6
Prehospital care	
Signs of life at the scene n (%)[b]	29 (93.5)
Prehospital CPR n (%)	19 (61.2)
Length of CPR, min	14.6±4.4
Glasgow Coma Score (GCS) at the scene (units, mean ± SD)	7.3±2.6
ED physiology	
ED signs of life n(%)[b]	15 (48.4)
Initial ED cardiac rhythm n(%)	
Sinus rhythm	13 (42)
Pulseless electrical activity	9 (29)
Asystole	7 (22.5)
VF/VT	2 (6.5)
Glasgow Coma Score (GCS) on admission to ED (units, mean ± SD)	5.54±1.9
Timing procedure	
TIME1 (minutes, mean ± SD)[c]	21.6±16.4
TIME2 (minutes, mean ± SD)[d]	23.58±7.78
ED therapeutic management	
Crystalloid fluids (ml, mean ± SD)	1851.6±1473.3
Packed cells (units, mean ± SD)	4.94±3.1
Fresh frozen plasma (units, mean ± SD)	3.45±2
Vasopressors' use n(%)[e]	8 (25.8)
Outcomes	
Survival until ICU n (%)	13 (42)
Survivor ICU length of stay (d), (mean ± SD)	
Overall six predominant thoracic trauma patients	7.38±1.2
Survivor hospital length of stay (d), (mean ± SD)	
Overall six predominant thoracic trauma patients	17.5±5.9

Notes: *Demographics and clinical characteristics are described for the entire study population. [a]Some trauma patients with predominant blunt and gunshot thoracic injuries also had other injuries: superficial facial and blunt soft tissue injuries of extremities (no fractures). [b]Signs of life include: detection of pulse, spontaneous breathing and verbal response [c]TIME 1 (min.) from admission to ED to start of resuscitative thoracotomy (EDT). [d]TIME 2-Length of procedure (EDT): [e] Norepinephrine.

Table 2 Predictors of survival after EDT: univariate analysis

	Survival (n=13)	Non-survival (n=18)	*P*-value*
Age, years (mean±SD)	29±12.1	34.6±15.16	0.25
Gender (male) (%)	12/13 (92.3%)	15/18 (83.3%)	0.62
Weight (kg, mean±SD)	79.76±12.73	73.94±17.97	0.32
Diagnosis			
Stab wound (n,%)	4/13 (30.8%)	2/18 (11.1%)	0.034
Gunshot wound (n,%)	2/13 (15.4%)	10/18 (55.6%)	0.067*
Blunt trauma (n,%)	7/13 (53.8%)	6/18 (33.3%)	0.043
RTS (units, mean ± SD)	8.2 ±2.3	7±3.5	0.2
ISS (units, mean ± SD)	39.15±15.76	40.55±14.63	0.8
CPR at the scene (n, %)	4/13 (30%)	10/18 (55%)	0.017
ED signs of life (n, %)	12 (92.3%)	3 (16.7%)	<0.001*
Initial ED sinus rhythm (n,%)	12 (92.3%)	1 (5.6%)	<0.001*
HR ED[a] (beats/min, mean ± SD)	90.15±49.9	75.2±59.32	0.045
HR EDT (beats/min, mean ± SD)[b]	93.18±12.14	37.55±19.7	<0.001*
pH arterial blood[b]	7.16±0.15	7.02±0.014	0.24
Packed cells (units, mean ± SD)	5.9±4.5	2.4±2.7	0.028*
TIME1 (minutes, mean ± SD)[c]	27.3±16.1	17.3±16.05	0.9
TIME2 (minutes, mean ± SD)[c]	112.3±70.9	23.2±9.95	<0.001*
Total positive balance[d] (ml, mean ± SD)	12125±1765.58	3872.2±2713.94	0.013*

Notes: [a]HR - heart rate at admission to ED.[b]HR - heart rate, pH, bicarbonate of arterial blood at the end of EDT. [c]TIME1 - Time (min) from admission to ED to start of resuscitative thoracotomy (EDT), TIME2 - Duration of procedure (EDT).[d] Total positive balance includes both crystalloid fluids and blood products (packed cells and fresh frozen plasmas) administered until discharge from the ED after EDT. *Statistically significant.

red blood cell units administered; and total positive balance after the EDT (fluid and blood products). Patients with penetrating stab wounds had a better EDT survival rate than those with penetrating gunshot wounds or predominant blunt chest trauma (30.8% vs 11.1%, *p*-0.034) (Table 2).

PEA or asystole on admission to the ED were both strongly associated with a high mortality rate: PEA was observed in 44.4% of nonsurvivors vs in 7.7% of survivors (*p*-0.045) and asystole was observed in 38.9% of nonsurvivors vs in 0% of survivors (*p*-0.025). Also, a GCS score of 3 at the scene of the injury and on admission to the ED was found to correlate with a poor outcome: A GCS score of 3 was found in 66.7% of nonsurvivors vs in 7.7% of survivors ($p<0.001$). Previously published studies on survival after EDT have documented the clinical data, intraoperative findings and outcomes of the surviving patients.[4,6,9] In the present study we recorded similar data regarding the 13 patients in our study group who survived the EDT procedure (see Table 3). In the final analysis, 6 (19%) of the 31 patients who underwent EDT survived until hospital discharge: 3 with penetrating thoracic injuries and 3 with blunt thoracic injuries (Table 3). All these 6 patients had sinus rhythm on discharge from the ED to the OR and 4 of them had a systolic blood pressure of more than 70 mmHg at this stage (Table 3). Four of the patients (13% of the entire group) were neurologically intact on discharge from the hospital (Table 3). Cardiac injuries and lung tissue lacerations were the most common intraoperative findings (see Table 3). There was no difference between the APACHE scores of the survivors and of the nonsurvivors on admission to the ICU (28.7±2.25 vs 29.6±4.32; *p*-0.2). Also, among the patients who were eventually discharged from the hospital, there was no difference between the ICU admission APACHE scores of the patients with penetrating thoracic injuries and of those with blunt thoracic injuries (19% vs 22%, *p*-0.12).

Discussion

Emergency thoracotomy is well described as being indicated in cases of life-threatening thoracic trauma.[11] The main indications for EDT in patients with thoracic trauma are evacuation of pericardial tamponade; direct control of intrathoracic hemorrhage from the heart or the great vessels; control of massive air embolism; open cardiac massage; and cross-clamping of the descending aorta to redistribute blood flow.[6,7] Among the various mechanisms

Table 3 Survivors after emergency department thoracotomy

#	Age	Vital signs after discharge from ED				Intraoperative findings	First day ICU stay		Discharge from ICU
		Mech[a]	HR[b]	SPB[b]	Pupils[c]		APACHE[d]	Survival[e]	d/c GCS[f]
1	28	stab	ST (140)	NR	no	LV penetrating wound	35	no	
2	46	stab	NSR (95)	75	yes	RV, pericardial wound	28	yes	15
3	18	GSW	ST (120)	95	yes	Intercostal artery and lung laceration	30	yes	15
4	35	blunt	ST (130)	60	yes	Chest wall and lung injuries	32	no	
5	20	blunt	ST (145)	65	NR	Lung lacerations	32	yes	15
6	20	stab	NSR (62)	170	yes	pericardial wound tamponade	25	yes	15
7	25	stab	ST (149)	70	no	RV&LV penetrating wound	38	no	
8	54	blunt	ST (125)	45	NR	RT lung contusion and lacerations	30	no	
9	21	blunt	ST (105)	73	yes	Lung lacerations	28	yes	12
10	31	blunt	ST (116)	66	no	Chest wall and lung injuries	34	yes	10
11	22	GCW	NSR (98)	61	no	LA&LV penetrating wound	35	no	
12	43	blunt	ST (140)	NR	no	Chest wall and lung injuries	38	no	
13	24	blunt	ST (104)	51	no	Severe RT lung contusion and lacerations	36	no	

Notes: [a]Mechanism of injury, GSW- gunshot wound. [b]HR- heart rate, SPB- systolic blood pressure at discharge from ED to OR. [c]Pupils reactive to light at discharge from ED to OR. [d]APACHE score first 24 hrs ICU stay. [e]ICU survival. [f]Glasgow Coma Scale score on discharge from hospital.
Abbreviations: NR, not recorded; NSR, normal sinus rhythm; ST, sinus tachycardia; LV, left ventricle; RV, right ventricle; LA, left atrium.

of injury, penetrating thoracic trauma has been shown to have the highest survival rate (15–21%).[1] Patients with blunt thoracic trauma who undergo EDT have the worst prognosis (survival rate of 0.7–2.4%).[1] Blunt thoracic trauma occurs almost exclusively in road traffic accidents as the result of rapid deceleration and consequent crushing of the chest.[12] The most common intra-thoracic injuries sustained following blunt trauma are hemothorax, great vessel disruption and lung contusion.[1] In our study the immediate post-operative survival rate following EDT was 19% (13 patients). Among these, there was no significant difference between those who sustained penetrating thoracic trauma (6 patients; 46%) and those who sustained blunt trauma (7 patients; 54%). Of the 6 thoracic trauma patients who survived until hospital discharge, 3 had sustained blunt thoracic trauma, 2 had sustained gunshot wounds and 1 had sustained a stab wound. Importantly, in contrast to previous publications, we demonstrated a relatively good eventual clinical outcome after predominant blunt thoracic trauma.[1,9]

In addition to the effect of the mechanism of injury on the clinical outcome of thoracic trauma patients, the following parameters have been shown in the past to have a strong association with the clinical outcome after emergency thoracotomy in the context of multiple trauma: the prehospital time interval; the presence or absence of vital signs at the scene of the injury and on arrival at the ED; the duration of prehospital CPR; the patients' age; the amount of blood transfusions administered; the coagulation profile; the base excess; the initial heart rate; and the GCS.[13–18]

In our study, we retrospectively analyzed the records of 31 trauma patients with predominant thoracic penetrating and blunt injuries who underwent EDT. We found that the presence of sinus rhythm and of signs of life on admission to ED predicted survival after EDT in patients with predominant thoracic trauma. Also, univariate analysis of the data showed that the presence of heart rate of 93.18±12.14 beats/minute at the end of EDT and a high total positive fluid balance after EDT (more than 12 L including crystalloid fluids and blood products) were positive predictors for survival following EDT. In contrast, we found that CPR at the scene of the injury was a risk factor for mortality. As has been suggested by other authors, this is possibly because those patients had an initially worse state and poorer prognosis.[15–19] Our results are consistent with the findings in previous studies that the presence of signs of life, sinus rhythm and GCS score of >7 are favorable predictors of survival in thoracic trauma patients who undergo EDT.[10,17–19] We demonstrated a relatively high survival rate after EDT in patients with blunt chest trauma. We suggest that this finding might be due to the rapidity of medical

evacuation of trauma patients in southern Israel to the Soroka Medical Center, reflected by the presence of signs of life in all 6 survivors on their arrival at the ED (a known favorable prognostic factor for survival after EDT). In view of this finding, it appears reasonable to suggest that some carefully selected blunt trauma patients should be considered for surgical management. This recommendation does not conform with the guidelines of the Eastern Association for the Surgery of Trauma.[1]

Our study has several limitations. It is retrospective and single-center and includes only a small number of patients. Being retrospective, the study was limited to the available data in the patients' medical records. Also, multivariate analysis was not performed because of a small number of patient population.

Conclusion

In summary, we found that the following are good prognostic factors for survival in patients with predominant thoracic trauma who undergo EDT: presence of signs of life on admission to the ED; sinus rhythm on initial presentation; heart rate above 80 beats per min at the end of EDT; short duration of EDT; and high positive cumulative fluid balance. Blunt trauma to the chest was found in this study to have better survival and hospital discharge rates than previously reported. There was no statistical difference in survival rate until discharge from hospital between penetrating and blunt trauma.

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Disclosure

The authors report no conflicts of interest in this work.

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