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Outcomes after emergency department thoracotomy for penetrating cardiac injuries: a new perspective

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Abstract

Previous reports have described penetrating cardiac injuries as the anatomic injury with the greatest opportunity for emergency department thoracotomy (EDT) survival. We hypothesize that actual survival rates are lower than that initially reported. A retrospective review of our EDT experience was performed. Data collected included injury mechanism and location, presence of measurable ED vital signs, initial ED cardiac rhythm, GCS, method of transportation, and survival. Logistic regression analysis identified predictors of survival. Ninety-four of 237 patients presented penetrating cardiac injuries after EDT. Eighty-nine patients (95%) were males. Measurable ED vital signs were present in 15 patients (16%). Cardiac injuries were caused by GSW in 82 patients (87%) and SW in 12 patients (13%). Fifteen patients (16%) survived EDT and were taken to the operating room, while eight patients (8%) survived their entire hospitalization. All survivors were neurologically intact. Survival rates were 5% for GSW and 33% for SW. Mechanism of injury (SW), prehospital transportation by police, higher GCS, sinus tachycardia, and measurable ED vital signs were associated with improved survival. In urban trauma centers where firearm injuries are much more common than stabbings, the presence of a penetrating cardiac injury may no longer be considered a predictor of survival after EDT.

Keywords: Trauma; Penetrating; Surgery; Emergency; Thoracotomy

1. Introduction

Emergency department thoracotomy (EDT), defined as the thoracotomy performed in the emergency department for patients arriving in extremis, has become an established procedure in the management of life-threatening penetrating injuries [1–3]. Current indications for EDT after penetrating injury include recent witnessed loss of signs of life (SOL) and persistent, severe hemorrhagic shock that precludes transport to the OR.

Outcome after EDT varies widely depending on the injury mechanism, anatomic injury location, and physiologic status. During EDT for penetrating trauma, the finding of a cardiac injury has traditionally been considered a positive prognostic factor, compared to findings of non-cardiac thoracic or abdominal injuries. A meta-analysis by Rhee et al. [4] determined that EDT survival rates were highest for isolated penetrating cardiac injuries (19%) compared to penetrating non-cardiac thoracic (11%), penetrating abdominal (4%), or multiple penetrating injuries (<1%). Overall survival rates were 17% after stab wounds and 4% after gunshot wounds. Normal neurologic recovery was observed in 92% of the patients who survived their hospitalization. However, the outcome analysis for cardiac wounds was not stratified by injury mechanism.

In our present study, we sought to assess our recent experience in the management of patients with penetrating cardiac injuries requiring EDT. The primary objective of this study was to identify predictors of survival for patients undergoing EDT after penetrating cardiac injuries in a busy urban trauma center where firearm injuries predominate.

2. Patients and methods

After Institutional Review Board approval, a retrospective chart review of all patients with penetrating injuries who underwent EDT at our level I trauma center between January 2000 and December 2006 was performed. EDT was performed in all patients who presented in extremis after sustaining penetrating extra-cranial injuries. Ninety-four of 237 patients that underwent EDT during the study period were found to have penetrating cardiac injuries and comprise our study population. All patients who underwent EDT for penetrating injury were included in this study. Patients with EDT performed for blunt trauma and all OR thoracotomies were excluded. The decision to perform EDT was based on the discretion of the attending trauma surgeon or senior surgical resident. In most cases, the procedure consisted of a left anterolateral thoracotomy, pericardio-

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tomy, open cardiac massage, and temporary distal descending thoracic aorta occlusion. Patients who survived EDT were emergently transferred to the OR for formal exploration and definitive injury repair.

Data collected included patient age and sex, mechanism of injury (stab wound vs. gunshot wound), method of hospital transportation (fire rescue, police and private vehicles), presence of field and ED signs of life (SOL), Glasgow Coma Scale (GCS), presence of measurable ED vital signs, initial ED cardiac rhythm, anatomic cardiac injury location, Injury Severity Score (ISS), hospital length of stay, hospital survival, and neurologic outcome. SOL were defined by the presence at least one of the following: pupillary response, spontaneous ventilatory effort, palpable carotid pulse, measurable or palpable blood pressure, extremity movement, or cardiac electrical activity. The presence of obtainable vital signs was defined by any of the following: palpable carotid pulse, measurable blood pressure, or spontaneous respiratory activity. Data analyzed in this series were extracted from a dataset utilized in previous work from this institution [5–7].

The primary outcome analyzed was neurologically intact hospital survival. Normal neurologic outcome was defined as functional status without any major sequelae and the ability to perform activities of daily living without difficulty. Descriptive statistics were calculated for continuous and categorical variables. Univariate logistic regression analysis was performed to identify predictors of survival to hospital discharge. A *P*-value ≤ 0.05 was considered statistically significant.

3. Results

Penetrating cardiac injuries were discovered in 94 of 237 patients (40%; 95% CI, 33–45%). Patient demographics and clinical characteristics are shown in Table 1. Patients were primarily young (28.4±10.4 [mean±S.D.] years) males (95%) injured by gunshot wounds (87%; 95% CI, 80–94%). Multiple gunshot wounds represented the most common injury mechanism (55%), but single gunshot wounds (32%) were also common. Thirteen percent (95% CI, 6–20%) of the patients sustained stab wounds (8% single, 5% multiple). An isolated injury to the left ventricle represented the most common cardiac injury location (24%), followed by an isolated injury to the right ventricle (20%), combined injury to the left ventricle and the right ventricle (9%), isolated injury to the right atrium (9%), combined right atrium and right ventricle (7%), combined left ventricle and aorta (6%), and other combinations (25%). Fifty-one percent of the patients were found to have a single cardiac injury.

Prehospital care was analyzed. Field SOL were observed in 60% of study patients and 43% underwent prehospital CPR. Forty-seven percent of the patients were transported by police, 45% by EMS, and 8% by private vehicle. Venous access was obtained in 33% of the cases. Thirty-seven percent of study patients underwent prehospital endotracheal intubation and 7% arrived to the ED in spinal precautions with cervical collar and long board in place.

Physiologic assessment included SOL, ED arrival vital signs, presenting cardiac rhythm, GCS, and ISS. ED SOL were observed in 44% (95% CI, 34–54%) of the patients while

Table 1
Demographics, clinical characteristics and outcome (*n*=94)

Age (years, mean±S.D.)	28.4±10.4
Gender (male)	89 (95%)
Mechanism of injury	
Single gunshot wound	30 (32%)
Multiple gunshot wounds	52 (55%)
Single stab wound	7 (8%)
Multiple stab wounds	5 (5%)
Cardiac injury location	
LV	22 (24%)
RV	19 (20%)
LV-RV	8 (9%)
RA	8 (9%)
RA-RV	7 (7%)
LV-Ao	6 (6%)
Other	23 (25%)
Single cardiac injury	48 (51%)
Field SOL	56 (60%)
Field CPR	40 (43%)
Venous access	31 (33%)
ETT	35 (37%)
Transport method	
Police	44 (47%)
Fire rescue	42 (45%)
Private	7 (8%)
ED SOL	41 (44%)
Measurable ED vital signs	15 (16%)
Initial ED cardiac rhythm	
Asystole	53 (56%)
Agonal	4 (4%)
PEA	26 (28%)
Sinus bradycardia	2 (2%)
Sinus tachycardia	8 (9%)
Normal sinus rhythm	1 (1%)
Initial GCS	3.7±2.5
ISS (0–75)	62.1±22.1
Overall survival	
Survived to DC	8 (8.5%)
Died in OR	7 (7.5%)
Died in ED	79 (84%)
LOS (days)	22.4±11.0
Normal neurologic outcome	8/8 (100%)

Ao, aorta; CPR, cardiopulmonary resuscitation; DC, discharge; ED, emergency department; ETT, endotracheal tube; GCS, Glasgow Coma Scale; ISS, injury severity score; LOS, length of stay; LV, left ventricle; OR, operating room; PEA, pulseless electrical activity; RA, right atrium; RV, right ventricle; S.D., standard deviation; SOL, signs of life.

vital signs were measurable in only 16% (95% CI, 9–23%). Analysis of the initial ED cardiac rhythm revealed that 56% of the patients arrived in asystole, 4% demonstrated agonal rhythms, 28% pulseless electrical activity, 2% sinus bradycardia, 9% sinus tachycardia, and 1% normal sinus rhythm. The mean (±S.D.) initial Glasgow Coma Scale was 3.7±2.5 and the mean (±S.D.) injury severity score for this cohort of patients was 62.1±22.1.

The mean (±S.D.) length of hospital stay was 22.4±11.0 days (range: 9–41 days) and the overall survival until hospital discharge was 8% (95% CI, 3–14%; 8 of 94 patients). Seven patients (7%; 95% CI, 2–13%) survived EDT but expired in the OR (5 patients in the GSW group and 2 patients in the SW group). None of the patients that survived until the OR required cardiopulmonary bypass during operative repair. All survivors were neurologically intact at hospital discharge.

An analysis of survival based upon mechanism of injury, number of cardiac injuries, and presence of ED vital signs

Table 2
Analysis of survival according to mechanism of injury, number of cardiac injuries and presence of ED vital signs

Stab wound	
Survived to hospital discharge	4 (33.3%)
Died in OR	2 (17.7%)
Died in ED	6 (50%)
Gunshot wound	
Survived to hospital discharge	4 (4.9%)
Died in OR	5 (6.1%)
Died in ED	73 (89%)
Single cardiac injury	
Survived to hospital discharge	7 (14.6%)
Died in OR	5 (10.4%)
Died in ED	36 (75%)
Multiple cardiac injuries	
Survived to hospital discharge	1 (2.2%)
Died in OR	1 (2.2%)
Died in ED	44 (95.6%)
Recordable ED vital signs	
Survived to hospital discharge	5 (33.3%)
Died in OR	4 (26.7%)
Died in ED	6 (40%)
Unobtainable ED vital signs	
Survived to hospital discharge	3 (3.8%)
Died in OR	3 (3.8%)
Died in ED	73 (92.4%)

ED, emergency department; OR, operating room.

Table 3
Univariate logistic regression analysis

Variable	OR	95% CL	*P*-value
Age	1.03	0.97–1.01	0.22
Gender	0.34	0.03–3.48	0.36
Mechanism of injury (SW)	0.10	0.02–0.49	0.004
Field SOL	5.28	0.62–44.8	0.12
ED SOL	4.37	0.83–22.9	0.08
Police transport	9.08	1.07–77.0	0.04
Fire rescue transport	0.15	0.01–1.30	0.08
Private transport	<0.01	<0.01–>99.9	0.97
Glasgow Coma Scale	1.36	1.12–1.65	0.002
Asystole	0.22	0.04–1.20	0.08
Agonal	<0.01	<0.01–>99.9	0.97
PEA	0.34	0.04–2.98	0.33
Sinus tachycardia	46.1	7.34–289.5	0.001
Sinus bradycardia	<0.01	<0.01–>99.9	0.98
Normal sinus rhythm	<0.01	<0.01–>99.9	0.98
Recordable VS in ED	12.6	2.62–61.2	0.002
Injury severity score	0.97	0.94–1.01	0.18
SVC injury	<0.01	<0.01–>99.9	0.97
IVC injury	1.37	0.15–12.6	0.77
RA injury	0.22	0.02–1.91	0.17
RV injury	2.50	0.56–11.1	0.22
LA injury	<0.01	<0.01–>99.9	0.98
LV injury	0.61	0.13–2.73	0.52
Aortic injury	<0.01	<0.01–>99.9	0.96
PA injury	<0.01	<0.01–>99.9	0.98
Single cardiac injury	7.33	0.86–62.1	0.06

CL, confidence limit; ED, emergency department; IVC, inferior vena cava; LA, left atrium; LV, left ventricle; OR, odds ratio; PA, pulmonary artery; PEA, pulseless electrical activity; RA, right atrium; RV, right ventricle; SOL, signs of life; SVC, superior vena cava; SW, stab wound; vs., vital signs.

is shown in Table 2. Four of 82 patients (5%) that sustained gunshot wounds survived while 4 of 12 patients (33%) with stab wounds survived. Seven of 48 patients (15%) with single cardiac injuries survived while 1 of 46 patients (2%) with multiple cardiac injuries was discharged from the hospital. This single survivor with multiple cardiac injuries suffered a SW to both ventricles. Five of 15 patients (33%) with recordable ED vital signs survived to hospital discharge while only 3 of 79 patients (4%) with without ED vital signs survived.

Univariate analysis (Table 3) identified the following predictors of survival: stab wound injuries, prehospital transportation by police, higher GCS, the presence of sinus tachycardia upon ED arrival, and measurable ED vital signs.

4. Comment

This study represents our experience in the management of ninety-four consecutive patients found to have penetrating cardiac injuries after EDT during a seven-year time period. The most important finding of the present study was that survival rates after EDT in patients with penetrating cardiac injuries secondary to gunshot wounds were significantly lower than survival rates for patients receiving stab wounds (5% vs. 33%, $P=0.02$). In our study population, patients who sustained cardiac stab wounds were nearly 17 times more likely to survive than those who suffered cardiac gunshot wounds.

Overall, 8% (95% CI, 3–14%) of our patients with penetrating cardiac injuries survived EDT. This survival rate is lower than that observed by Rhee et al. [4] in his comprehensive meta-analysis. He reported that 19% of patients with penetrating cardiac injuries survived EDT and documented a higher mortality associated with gunshot wounds for all injury locations (cardiac, thoracic non-cardiac and abdominal). However, an outcome analysis of cardiac wounds according to the mechanism of injury was not performed. We believe that the prevalence of gunshot wounds in our study population and poor survival after cardiac firearm injuries may explain the discrepancy in outcomes.

Over the last two decades, reports from our institution and others have identified several survival predictors following EDT including injury mechanism, injury location, time to EDT, initial cardiac rhythm, and the presence of vital signs or signs of life (SOL) [4, 8–11]. But EDT survival predictors are not always reliable [5]. The present overall survival rate of EDT for penetrating cardiac injuries (8%) for example, is lower than that we recently reported for prelaparotomy EDT during abdominal exsanguination (16%) [6]. A high incidence of gunshot wounds with multiple cardiac chamber injuries in the present study may explain these findings. It has been demonstrated that the physiologic condition of patients with penetrating cardiac injuries upon ED arrival is associated with the mechanism of injury [8]. Patients sustaining gunshot wounds have been found to present with a worse physiologic status as evaluated by the cardiovascular-respiratory component of the Trauma Score. This may be secondary to a higher incidence of exsanguinating cardiac wounds in patients with firearm injuries as opposed to tamponade as in stabbed patients.

In our present study, we sought to identify predictors of survival after EDT for patients with penetrating cardiac injuries. Univariate logistic regression analysis identified stabbing injury mechanism, prehospital transportation by police, a higher Glasgow Coma Scale, the presence of sinus tachycardia upon ED presentation, and measurable ED vital signs as predictors of survival to hospital discharge.

Method of prehospital transportation was predictive of survival in the present series. Transportation by police was a positive survival determinant. As previously reported, the performance of prehospital procedures in patients with critical penetrating injuries may have a negative impact on EDT survival [7]. This finding may be explained in two ways – either too much time is spent performing these pre-hospital procedures, the interventions and the pre-hospital resuscitation itself are detrimental, or a combination of both. While we did not analyze pre-hospital transportation times in our present study, another theory that has been well studied is permissive hypotension. At lower blood pressures (systolic blood pressure <90 mmHg), injured structures tend to coagulate, reducing further bleeding. If a patient is aggressively resuscitated with IV fluids before definitive surgical control is achieved and blood pressure rises to 'normal' values, the injury clot may 'pop' and hemorrhage is exacerbated. This theory has been directly studied in animal models [12] and indirectly studied in human penetrating trauma victims by measuring bleeding and mortality after patients were randomized to aggressive IV fluid resuscitation or minimal fluid resuscitation groups [13].

The present study has several limitations that we should consider. This is a retrospective review from a single institution where the majority of our patients are brought from nearby neighborhoods. Patients with cardiac injuries who were pronounced 'dead on arrival' were not assessed in this present report. As such, only patients who underwent EDT and were found to have cardiac injuries were analyzed. Our reported survival may be inflated from actual values if post-mortem studies were included. Furthermore, we recognize that the statistical power of the study is limited by the small sample size with our primary outcome measure (hospital survival). Finally, we did not compare the outcome of exsanguinating cardiac injuries to patients presenting with pericardial tamponade, two injury manifestations which likely have profound effects on patient survival [14].

In conclusion, EDT survival after cardiac GSWs was poor in our study population. Based on our findings, we conclude that in urban trauma centers where gunshot wounds are more common than stab wounds, the presence of a penetrating cardiac injury should not be considered a predictor of EDT survival. Further study is warranted to improve patient selection and maximize positive outcomes while avoiding the costs and risks [15] associated with EDT in non-salvageable patients.

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eComment: Emergency department thoracotomy and middle income countries

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For several decades after its introduction to surgical practice in the early 1900s, emergency department thoracotomy (EDT) yielded poor statistical outcome because it was indiscriminately applied to all moribund trauma patients.

Reports from high-income countries, as well as the article by Molina et al. [1], have documented improvement over the past three decades after implementation of strict management protocols with well-defined selection criteria [2–3].

In order to improve our management protocols of comprehensive assessment of the acute and long-term treatment of patients with penetrating cardiac injuries, last year we retrospectively examined records from our University Clinic Cardiovascular Department (UCCD) over a period of 11 years, from January 1995 to January 2006.

Factors that were found to be predictive of early mortality included gunshot wounds, extra-thoracic injuries, prolonged transportation times [transport duration (survivors, n=10), median (range), min- 150 (15–180); (no survivors, n=11) min- 220 (30–210)] and absence of signs of life on presentation. Victims of cardiac trauma for EDT were not stable enough to withstand the delay for transfer to the operating room.

Report by the Philadelphia's group has documented improved outcomes, but these results are not easily reproducible in middle and low-income countries where support services and facilities are not readily available [4]. Moreover, the authors did not analyze pre-hospital transportation times and our data suggested that without adequate pre-hospital resuscitation, longer transport times will herald worse outcomes.

Despite these limitations, the early survival at the UCCD is comparable to that in larger reports from high-income countries.

Several reports have identified the absence of signs of life on arrival at the hospital as a herald of mortality [5]. Similarly, this was noted to be predictive of early mortality in our series.

The fact that EDT is one of the last maneuvers that may preserve life cannot justify its indiscriminate use because there are several complications. The cardiovascular and trauma team is at high risk for percutaneous injuries, blood exposure and disease transmission. Additionally, the financial demands cannot be underscored, especially in middle-income countries where resources are scarce with the health care systems being under-funded. The quality of life in survivors is also of valid concern. The survivors in our series required constant home supervision due to neurologic impairment, much to the distress of his caregivers.

It is time to implement strict protocols to exclude futile operations in unsalvageable patients and we must tailor the indications to suit our local health care environment.

Several limitations of the health care system have been uncovered in Croatia that are likely reflective of most middle-income countries. They must be addressed if we are to expect improved outcomes. Importantly, our data suggested that the UCCD should stock a special EDT kit that contains the basic equipment necessary for this procedure.

Moreover, quantified data represented by Molina et al. could assist young cardiovascular surgeons in the middle-income countries, in the management of penetrating cardiac wounds in a scope of properly EDT indications.

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