Emergent Exploratory Thoracotomy with Military Casualties: Contemporary Prehospital Management and Outcome

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ABSTRACT

Background: Chest trauma is among the most common types of trauma, corresponding to 10% of trauma patients admitted to hospitals. In the military setting, thoracic trauma was reported as a significant cause of death. With well-timed treatment, chest trauma is regarded as survivable. Emergency thoracotomy (ET) is considered when the patient with trauma to the chest needs immediate resuscitation. Survival rate is reported as low as 1% in some reports and 20% in others. The survival rate depends on injury mechanism, protocols for intervention, and other decompressive procedures.

Objectives: To determine parameters that may impact survival of ET.

Methods: We conducted a retrospective cohort study to compare prehospital and in-hospital data regarding ET in the emergency department (ED) versus the operating room (OR).

Results: Between 2009 and 2017, 6532 casualties presented to the ED; 1125 with trauma to the chest. Fifty-four of those with chest trauma underwent ET in the hospital (4.8%), 22 (41%) in the ED, and 32 (59%) in the OR. The overall mortality of the ET subgroup was 48%. With regard to thoracotomies, 19/22 of patients (86%) who underwent ET in the ED died compared to 2/28 in the OR (13%).

Conclusions: Utilizing ET after chest trauma with appropriate clinical indications, well-trained personnel, and prompt transportation poses a significant challenge, but may be associated with better survival than that reported previously with military casualties. Adoption of indications and timed allocation to the OR may improve outcomes with chest trauma casualties.

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Chest trauma is among the most common types of trauma, corresponding to 10% of the trauma patients admitted to hospitals [1]. Even though reported associated mortality is low, with death as an outcome in only 1.7% [2], chest trauma has the potential of being a devastating injury. The most frequent injuries to the chest are spine fractures (30.4%), followed by rib fractures (23.2%), and pneumothorax (16.8%) [2]. Chest trauma is regarded as survivable [3], given well-timed treatment. Intensive care admission was reported in 14%, oxygen treatment in 30.6%, and mechanical ventilation in only 5.8%. [2]. Nevertheless, major trauma involving vital organs usually leads to rapid physiologic deterioration and death. The factors stated as predicting death include injury mechanism (blunt versus penetrating), injury location, and signs of life on arrival to the hospital [4].

Emergency thoracotomy (ET) is considered when the patient with trauma to the chest needs immediate resuscitation. Overall survival rate of an ET is reported as low as 1% in some reports and as high as 20% in others [5,6]. Mechanism of injury is of utmost importance, with survival rates for ET for penetrating injuries reported as 8.8% and only 1.4% for blunt injuries. Some medical centers follow a protocol in which ET is considered only after a penetrating injury mechanism rather than blunt [7]. Moreover, in a retrospective study including 1377 consecutive, critical blunt trauma patients, 484 (35.1%) underwent ET [7], and 893 (64.9%) received closed-chest compressions. Compared to closed-chest compressions, ET was associated with a lower survival rate.

Well-trained personnel can reach a high survival rate by implementing the suitable trauma protocol, as demonstrated in the single-surgeon report by Rabinovici [8], who succeeded in resuscitating 9 of 68 (13%) chest trauma patients (75% of whom presented with penetrating trauma). Survival following ET is

reported variably and is defined by some authors as restoration of vital signs and transport out of the trauma resuscitation area to the operating room [4] and by others as 24 hours and 30 days postoperative survival.

In the military, thoracic trauma has been reported as a significant cause of death. From World War II [9] until the Korean War [10], the fatalities from chest trauma were declining from 50% toward 5%, respectively. This improvement over the decades of armed conflict in casualty rate was due to blood transfusions, aseptic surgery, and the availability of transportation to definitive care. Still today, chest trauma is a leading cause of combat fatalities [10].

We evaluated which parameters may impact survival with casualties who underwent ET. We reported the demographic characteristics, medical treatment, and outcomes of casualties presenting with chest trauma who underwent ET in the hospital.

PATIENTS AND METHODS

STUDY DESIGN

In this retrospective registry-based cohort study, the Israeli Defense Forces prehospital trauma registry (IDF-TR) was cross-linked with the Israel National Trauma Registry (INTR). Hospitalized trauma cases between January 2009 and December 2017 were used. The Israel Defense Forces Medical Corps (IDF-MC) institutional review board approved the study (No. 2014–1948) and waived the requirement for written informed consent.

The IDF-TR is a computer-based trauma registry operated by the Trauma and Combat Medicine Branch at the IDF-MC Surgeon General's Headquarters. Data obtained by the IDF-TR include casualty cards completed by point of injury (POI.) caregivers, similar to the Tactical Combat Casualty Care card. The IDF-MC casualty card records vital signs, interventions performed at the POI, demographics, mechanisms, and anatomic distribution of injuries.

The INTR at the National Center for Trauma and Emergency Medicine Research at the Gertner Institute for Epidemiology and Health Policy Research collects data from 21 trauma centers in Israel, including all six level I trauma centers. All patients hospitalized after being admitted to the emergency department (ED) due to injury and assigned an International Classification of Diseases 9 Clinical Modification (ICD-9-CM) diagnosis code between 800 and 959.9 are included in the INTR. The registry records all casualties admitted to the hospital, including casualties who die in the ED or are transferred to another hospital following injury. It does not include casualties who died at the scene or on their way to a hospital, or those who were not hospitalized. Data reported to the INTR are recorded by trained trauma registrars at each trauma center under the supervision of the trauma director and the trauma coordinator. Electronic files are transferred to the Israel National Center for Trauma and Emergency Medicine Research, where quality assurance is conducted prior to the data being analyzed. Quality assurance included both logical tests preset in the registry software and in-depth manual testing of logic and missing data by INTR employees.

STUDY POPULATION AND CLINICAL PRACTICE

We extracted data on soldiers who sustained a chest injury recorded in the IDF-TR within the study period. We cross-linked the registry with the INTR. Casualties for whom there was no identification number or who were not hospitalized in one of the 21 hospitals included in the INTR were excluded.

THORACIC INJURY MANAGEMENT IN THE IDF

The IDF-MC Clinical Practice Guidelines (CPG) on thoracic injury were published in July 2012 and advocate prehospital intervention such as needle thoracostomy (NT) or tube thoracostomy (TT) for profound hemodynamic shock or sudden loss of vital signs throughout resuscitation in a casualty who sustained a chest injury.

Only advanced life support providers (paramedics and physicians) can diagnose and decompress chest injuries by either NT or TT. On arrival to a trauma center, the trauma team is in charge of all clinical decisions regarding the casualty, including the decision for an ET. The main indications treated were hypotension, not responding to resuscitation with hemothorax, thoracostomy, drainage of more than 1500 ml, radiographic signs of cardiac tamponade, clinical suspicion of air emboli, signs of a tracheobronchial tear with massive air leak, and abdominal injury necessitating aortic clamp.

Thoracotomies performed within one hour of arrival to the hospital were included. Otherwise, they were categorized as urgent and excluded. On arrival to the hospital, dead patients (absence of vital signs for more than 15 minutes and 5 minutes in penetrating and blunt trauma) were also excluded, even if heroic efforts such as ET were performed.

VARIABLES

Demographics, POI, and prehospital data extracted from the IDF-TR included: identification number, date of injury, whether the incident was military, the casualty's age and sex, level of urgency for evacuation, mechanisms of injury, injured body regions, care provider's profession, prehospital interventions performed (including NT and TT), evacuation mode of transplantation, and fatality. The mechanism of injury was categorized as penetrating or blunt. Injuries of the chest, upper abdomen, and upper back were categorized chest. The investigated life-saving interventions included tourniquets, hemostatic dressing, endotracheal intubation, cricothyroidotomy, crystalloids, freeze-dried plasma, packed red blood cells, tranexamic acid, and anesthesia.

ED and hospital data extracted from the INTR included: vital signs on arrival at the hospital, injury severity score, Glasgow Coma Scale (GCS), ICD-9-CM codes for diagnoses and procedures, hospital length of stay, intensive care unit admission and

length of stay, and outcome at discharge (death, release home, or release to rehabilitation).

DATA ANALYSIS

Data analysis employed R version 3.6.1 (R Core Team, Vienna, Austria). Comparison of categorical variables was performed with the chi-square test. Quantitative variables were compared using the Mann–Whitney U test. Categorical variables are presented as n (%), and continuous variables as median (interquartile range) as appropriate. Significance was set at a *P*-value of 0.05.

RESULTS

In the study period, of 6532 casualties, 1125 (17%) presented with trauma to the chest. Fifty-four casualties who sustained chest trauma underwent emergency thoracotomy in the hospital (4.8%). The mean age of casualties was 21.5 ± 3.6 years; 96% were males. Penetrating trauma was observed in 31 casualties (57%) and blunt trauma in 23 casualties (43%). Twenty-two (41%) casualties underwent ET in the emergency department (ED), and 32 casualties (59%) underwent ET in the operating room (OR).

Regarding the physiological state of casualties:

- Hemodynamically mean systolic blood pressure on arrival to the ED was 107 ± 49 mmHg; the mean heart rate was 100 ± 46 bpm
- Respiratory rate was 17, mean PO2 was and 83 ± 30 mmHg, mean oxygen saturation nadir was 93% ± 7%

Regarding prehospital treatment for the 54 casualties, chest tubes were inserted before hospital admission in only 24% of the casualties who underwent ET. Surgical airway was utilized in 6.5%. Seven patients received blood products (five packed red blood cells and two fresh dried plasma), and tranexamic acid was given to four casualties prehospital arrival.

The overall mortality of the ET subgroup was 48%. Comparing the ED and OR thoracotomies, most of the patients (19 of 22, 86%) who underwent ET in the ED died compared to those who underwent the procedure in the OR (2 of 28, 13%), $P < 0.001$ [Figure 1]. Of note, one-third of the patients who underwent ET in the Ed underwent an additional OR re-exploration (8 of 22, 36%). Three of the re-explorations were successful, and the patients survived. Mechanism of injury (blunt vs. penetrating) did not differ between these subgroups (ED vs. OR, $P = 0.8$) [Figure 2]. Interestingly, although physiologic parameters or GCS were not different among the subgroups, there were significantly more head and extremities injuries ($P = 0.017$) with the ED group.

The subgroup in the ED also received more prehospital tranexamic acid and more blood products compared to the OR subgroup ($P = 0.003$ and $P = 0.017$, respectively). However, other than lower mean heart rate, the vital signs of the ED subgroup casualties did not differ. Regarding pre-admission interventions, the ED subgroup was subjected to less interventional treatment, namely NT or TT, before arriving at the hospital.

Figure 1. Survival rate in different location of emergent thoracotomy, (chi-square 21.7, $P < 0.001$)

ED = emergency department, OR = operating room

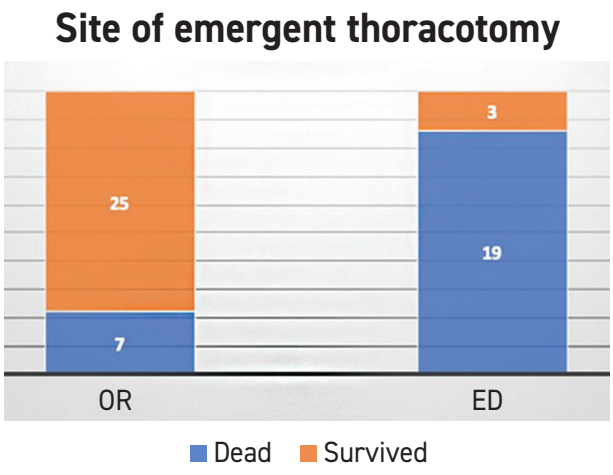
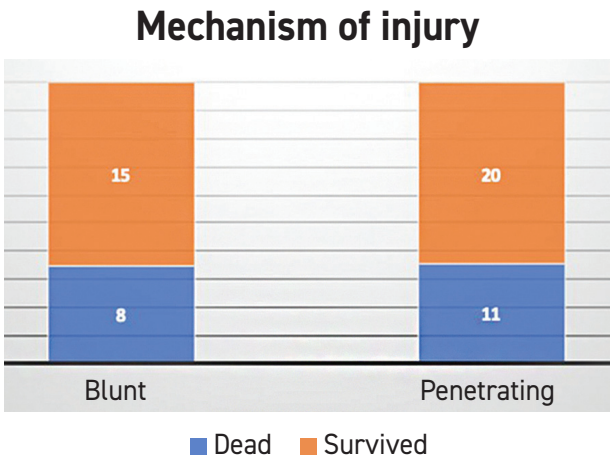


Figure 2. Survival rate for the type of injury (chi-square 0.0028, $P = 0.96$)



DISCUSSION

In this retrospective cohort study, we described the contemporary outcome of ET performed in the ED vs. the OR. Of the casualties who underwent ET, 52% of casualties survived the procedure and were discharged from the hospital alive. This survival rate is higher than expected compared to the literature [11]. In a literature review by Aseni et al. [12], the survival rate of ET following a penetrating injury was 15–35%, depending on the shock status, and was only 2% of the blunt injury subgroup.

Occasionally ET reports include patients with no vital signs on admission to the ED, not following current guidelines, or not reporting the inclusion criteria. In our study, only casualties alive on admission met the inclusion criteria, explaining part of the better outcome. Adhesion to ET indications and criteria, in addition to short transportation distances and well-trained military medical teams, may have contributed to the better survival we reported in this study.

We found that the survival rate was significantly higher with the subgroup in which ET was performed in the OR ($P < 0.001$). Nevertheless, there is an inherent selection bias between the OR and ED. The decision to continue to the OR may suggest less severe injuries, patients operated in the ED were found to have more head and limb injuries than the OR subgroup. Moreover, we found those blood products were administrated at a higher rate to the ED subgroup ($P < 0.017$).

Thoracostomies, whether needle or tube, were not predictive of clinical outcome for casualties who underwent ET. Most ET patients did not undergo thoracostomies before arriving at the hospital (40/54, 74%). These interventions are not well studied in the prehospital trauma setting, and practices vary as suggested by various reports [13-15]. In the current study caregivers followed standard IDF CPG for chest trauma that by itself may have reduced the need for hospital ET.

LIMITATIONS

As a retrospective study based on two national databases, the IDF-TR was cross-linked with the INTR. There are limitations to such analysis. Moreover, some clinical outcomes such as neurological deficits at follow-up are not available. This may have been interesting to compare given the two different ET studied.

CONCLUSION

In this study, we explored the unique characteristics and outcomes of casualties treated by IDF medical teams who underwent ET on arriving at the hospital following a trauma injury. Utilizing ET after chest trauma with appropriate clinical indications, well-trained personnel, and prompt transportation (with or without intervention before hospital admission) poses a significant challenge. Meeting this challenge may be associated with better survival than that reported previously with military casualties. Moreover, the adoption of indications and timed allocation to the OR may improve outcomes with chest trauma casualties. Randomized controlled trials may be challenging, but perhaps a future retrospective analysis of adequate data will indicate which approach is most appropriate for managing chest trauma and thus further improving outcomes.

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One day work is hard, and another day it is easy; but if I had waited for inspiration I am afraid I should have done nothing. The miner does not sit at the top of the shaft waiting for the coal to come bubbling up to the surface. One must go deep down, and work out every vein carefully.

Sir Arthur Seymour Sullivan (1842–1900), English composer