Clinical Outcome of Urgent Thoracotomy in Patients with Penetrating and Blunt Chest Trauma: A Retrospective Survey

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Keywords
- urgent thoracotomy
- blunt chest trauma
- penetrating chest trauma emergency thoracoscopy

Abstract

Introduction  In contrast to an emergency department of thoracotomy (EDT), an urgent thoracotomy (UT) is defined as a surgical thoracic intervention performed in the operating room within the first 48 hours of the patient’s intensive care unit (ICU) stay. The factors affecting survival after UT are not fully understood. In this study, we retrospectively analyzed the clinical data and outcome of patients with blunt and penetrating chest injuries who underwent UT.

Methods  All adult patients who had blunt or penetrating chest trauma and who underwent UT, were included in the study. All data were collected from the patients’ hospital and ICU records. Forty-five patients with thoracic injuries who underwent UT during the first 48 hours of ICU stay were analyzed. Of these, 25 had penetrating chest injuries, and 20 had blunt thoracic injuries. Of the penetrating injuries, 16 were stab wounds, and 9 were gunshot wounds.

Results  Overall ICU mortality was 29% (n = 13) and was significantly higher in the blunt chest trauma group than in the penetrating trauma group (45% vs 16%; p = 0.04). Lung parenchymal injuries (lacerations and contusions) were the most common intraoperative findings in both groups. The following independent predictors of in-hospital mortality were found: an Injury Severity Score (ISS) of >40; an Acute Physiology and Chronic Evaluation II (APACHE II) score of >30; prolonged duration of UT; low body temperature on admission to the ED; abnormal arterial blood lactate, bicarbonate, and pH at the end of UT; and use of vasopressors during the first 24 hours of ICU stay.

Conclusion  Mortality after UT was higher in patients with blunt chest trauma. The UT should be performed in both penetrating and blunt chest trauma as quickly as possible and should be limited to damage control. It also emerges that acidosis and hypothermia in chest trauma patients need to be treated extremely aggressively before, during, and after UT.

* Both authors contributed equally to this work.
Introduction

Severe chest injury is associated with high rates of morbidity all over the world.\(^1\) It occurs in >50% of cases of multiple trauma and is associated with a high mortality rate (~25%).\(^1,2\) The majority of penetrating and blunt chest injuries can be managed nonoperatively by thoracic tube drainage and supportive measures,\(^3\) but ~30% of penetrating and 10 to 15% of blunt chest trauma patients may require surgical intervention (thoracotomy or thoracoscopy).\(^3\) In contrast to an emergency department thoracotomy (EDT), which is usually performed in the emergency department (ED) as a resuscitative measure, an urgent thoracotomy (UT) is considered to be a surgical intervention performed in the operating room (OR) within the first 48 hours of ICU stay after injury.\(^4\) Only a few reports concerning UT have been published in the last few years.\(^4,5\) Although the indications for UT are similar irrespective of whether the injury mechanism is blunt or penetrating,\(^4\) nonetheless patients with blunt thoracic injuries who undergo UT have a worse prognosis than those with penetrating injuries.\(^5\) In recent publications, concomitant non-thoracic trauma and/or serious hemorrhage have been shown to correlate with poor outcome.\(^6,7\) However, all the factors affecting survival after UT are not fully understood.

Soroka Medical Center is a Trauma Level I Medical Center with extensive experience in civil and military trauma. In the present study, we retrospectively analyzed the association between the clinical data and the eventual outcome of patients with multiple trauma who underwent UT for blunt and penetrating chest injuries during the first 48 hours of their ICU stay.

Methods

Soroka Medical Center is a 1,000-bed tertiary-care Trauma Level I, university teaching hospital located in southern Israel. It takes care of ~1,500 to 2,000 trauma patient admissions per year of whom ~20% have some degree of chest trauma. The present study, which was retrospective and single-center, was approved by the Human Research and Ethics Committee at Soroka Medical Center in Beer Sheva, Israel (RN-0124–15–SOR). The study period is described retrospective data over past 10 years. Because the study was retrospective, no informed consent was required from the patients.

Inclusion Criteria

All trauma patients, aged ≥18, who had blunt or penetrating chest injury and who underwent UT during the first 48 hours after admission to the general and cardiothoracic ICUs were eligible for the study. Advanced Trauma Life Support (ATLS) guidelines were used for initial assessment. A patient was considered to have survived if he/she was alive when discharged home from the trauma center or transferred to the rehabilitation service.

Exclusion Criteria

Multiple trauma patients with blunt or penetrating chest trauma who underwent EDT and patients with chest injuries who did not undergo a thoracotomy procedure during the first 48 hours of their ICU stay were excluded from the study.

Procedure

The decision to perform UT 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).\(^5\) UT was performed at the discretion of an attending thoracic surgeon or trauma specialist on all patients who presented with penetrating or blunt thoracic injury. The indications for thoracotomy included an initial chest tube output of >1,000 mL or continued output of 250 mL/h for 3 successive hours followed by deterioration of hemodynamic condition; massive hemothorax associated with shock (systolic blood pressure <90 mm Hg); signs of pericardial tamponade; massive air leak; or radiographic evidence of a large hemothorax (opacification of more than half of the involved lung on a plain chest radiograph).\(^8\) Thoracotomy was performed while the patient positioned in 30°, through anterolateral incision sided according to the involved lung injury. In the three cases of cardiac injuries, the access was through mid-sternotomy. In one case of tracheobronchial injury, the access was through right posterolateral thoracotomy.

Variables and Measures

Data were collected from the patients’ hospital and ICU electronic records and from their laboratory database. We recorded demographic data, underlying co-morbidities, duration of ICU and hospital stay, period of time between admission to the ICU and performance of UT, duration of UT, intraoperative blood loss volume, intraoperative findings, the Injury Severity Score (ISS), and the Acute Physiology and Chronic Evaluation II (APACHE-II) score. We also collected the following clinical and laboratory data as recorded at ER admission and at the conclusion of UT: urine output per hour, total fluid balance per hour, heart rate, arterial blood pressure, body temperature, central venous pressure parameter, arterial blood pH and lactate, bicarbonate levels, blood glucose, urea, creatinine, sodium and chloride levels, hemoglobin level, platelet count, and respiratory parameters. The following ICU data were also recorded: radiological data, cardiopulmonary resuscitation (CPR) measurements (if documented), and therapeutic management during the first 48 hours of ICU stay.

Scores

The ISS, an anatomical scoring system which is used for the evaluation of all trauma patients on admission to the ED in our hospital, was recorded for each patient. Severity of critical illness and multiorgan failure were evaluated using the APACHE II score for each patient who was hospitalized in the general or cardiothoracic intensive care units.

Statistical Analysis

For categorical variables, proportions were compared using Fisher’s Exact Test or chi-square as appropriate. Continuous variables were analyzed using 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**

During the 10 years’ study period, 45 patients underwent UT, and 31 patients underwent ED Thoracotomy. Overall survival of the UT group was 29%, and for the ED group, it was 19% (16/31), which reflected the severity of the injury in those two different groups of patients. Data about elective thoracotomy indicated for late complications in trauma patients were not included in this study.

The clinical and laboratory data of 45 patients with thoracic injuries who underwent UT during the first 48 hours of ICU stay were analyzed. Importantly, all of them were examined by attending thoracic surgeon or trauma specialist during ED stay. No one did require emergent surgical procedure. Twenty-five (55%) patients presented with penetrating chest injuries and 20 (45%) with blunt thoracic injuries. The penetrating chest trauma group included 16 patients with stab wounds (64%) and 9 patients with gunshot wounds (36%). Other injuries sustained by the study patients included superficial facial and blunt soft tissue injuries of the extremities. None of the patients had fractures of the extremities. Importantly, all penetrating and blunt chest trauma patients underwent computed tomography (CT) imaging before UT procedure. The patients’ epidemiological and clinical characteristics are summarized according to mechanism of injury in Table 1. The blunt and penetrating injury groups were similar in age, weight, ISS, and APACHE scores.

Male gender was more frequent in the penetrating chest injury group than in the blunt trauma group. Indications for UT were ongoing high chest tube output, shock, and massive air leak, but there were differences in the indications for UT between the penetrating and blunt trauma groups. The patients with blunt chest trauma had a higher frequency of massive hemothorax associated with shock as the indication for UT (Table 1). Among the patients with gunshot penetrating chest injuries, there were two cases of massive air leak leading to UT (Table 1). Hemothorax and pneumothorax on CT were the most common findings in the patients with penetrating trauma. Among the blunt chest trauma patients, there was a higher frequency of rib fractures and lung contusions (p < 0.001) (Table 1).

There were no differences between the two groups in regard to heart rate and systolic blood pressure on admission to the ED and at the conclusion of UT (Table 1). The patients with blunt chest trauma had lower arterial blood pH and bicarbonate levels and higher lactate levels at the end of the procedure (UT) compared with those in the patients with penetrating trauma (Table 1). The duration of the procedure was the same in both groups. There was no difference in chest tubes output prior to UT between the two groups (Table 1). Both groups had the same therapeutic ICU measurements. The patients with blunt chest trauma had a higher rate of on-site CPR (50% vs 16%, p = 0.017). The data about “field CPR” was received from Israel emergency medical services. The reasons were the same as in another CPR case: no pulse or pulseless rate. Actually, there is a very low percent of true non-resuscitative trauma case on the field. It is difficult to distinguish between resuscitative or non-resuscitative case, even in blunt chest trauma, until you do not start CPR. None of our patients who survived after field CPR needed to be treated by EDT.

Table 1 Overall data of all trauma patients with penetrating and blunt thoracic injuries (n = 45)

<table>
<thead>
<tr>
<th>Demographic data</th>
<th>Penetrating (n = 25)</th>
<th>Blunt (n = 20)</th>
<th>p Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (mean ± SD)</td>
<td>28.6 ± 13.29</td>
<td>32.4 ± 12.54</td>
<td>0.33</td>
</tr>
<tr>
<td>Gender (male) (%)</td>
<td>24/25 (96%)</td>
<td>12/20 (60%)</td>
<td>0.004</td>
</tr>
<tr>
<td>Weight (kg, mean ± SD)</td>
<td>72.7 ± 7.09</td>
<td>69.75 ± 7.65</td>
<td>0.24</td>
</tr>
</tbody>
</table>

| Injury and ICU scores |
|-----------------------|-----------------|-----------------|---------|
| ISS (units, mean ± SD) | 29.2 ± 19.7 | 35.6 ± 12.65 | 0.22 |
| APACHE (units, mean ± SD) | 25.56 ± 4.83 | 30.47 ± 4.33 | 0.002 |

<table>
<thead>
<tr>
<th>Indications for urgent thoracotomyb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest tube output (n, %)</td>
</tr>
<tr>
<td>Massive hemothorax associated with shock (n, %)</td>
</tr>
<tr>
<td>Massive air leak (n, %)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CT findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemothorax (n, %)</td>
</tr>
<tr>
<td>Pneumothorax (n, %)</td>
</tr>
<tr>
<td>Rib fracture (multiple) (n, %)</td>
</tr>
<tr>
<td>Lung contusion (n, %)</td>
</tr>
</tbody>
</table>
There were no differences in the duration of ICU and hospital stay between the two groups (\(\text{Table 1}\)). The ICU mortality rate was significantly higher in the blunt chest trauma group than in the penetrating trauma group (45% vs 16%) (\(\text{Table 1}\)). Overall ICU mortality was 29% \((n = 13)\). The main causes of death in both the penetrating and the blunt chest trauma groups were multiple organ failure secondary to septic processes and severe coagulopathy.

Lung parenchyma injuries (lacerations and contusion) were the most common intraoperative findings in both groups (\(\text{Table 2}\)). Intercostal artery lacerations were detected in seven patients with penetrating injury and in five with blunt injury (\(\text{Table 2}\)). Two patients with gunshot wounds had tracheobronchial lacerations (one involving the trachea and one a main bronchus), and one patient with blunt trauma sustained a laceration involving a main bronchus (\(\text{Table 2}\)).

\(\text{Table 3}\) shows the results of univariate analysis of the clinical and laboratory parameters of the patients who underwent UT during the first 48 hours of their ICU stay. Of these parameters, the following were independent predictors of

<table>
<thead>
<tr>
<th>Clinical and laboratory parameters</th>
<th>Penetrating</th>
<th>Blunt</th>
<th>(p) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>HR-ED (b/min, mean ± SD)</td>
<td>111.6 ± 18.62</td>
<td>117.7 ± 18.54</td>
<td>0.43</td>
</tr>
<tr>
<td>HR-UT (b/min, mean ± SD)</td>
<td>98.22 ± 28.64</td>
<td>93.83 ± 52.48</td>
<td>0.75</td>
</tr>
<tr>
<td>SBP-ED (mmHg, mean ± SD)</td>
<td>73.07 ± 25.02</td>
<td>61.78 ± 21.15</td>
<td>0.27</td>
</tr>
<tr>
<td>SBP-UT (mmHg, mean ± SD)</td>
<td>96.36 ± 25.4</td>
<td>91.3 ± 29.8</td>
<td>0.15</td>
</tr>
<tr>
<td>(p) arterial blood</td>
<td>7.27 ± 0.09</td>
<td>7.12 ± 0.17</td>
<td>0.007</td>
</tr>
<tr>
<td>Body temperature-ED (°C, mean ± SD)</td>
<td>35.98 ± 1.9</td>
<td>34.09 ± 2.7</td>
<td>0.11</td>
</tr>
<tr>
<td>Lactate arterial blood (mmol/L, mean ± SD)</td>
<td>4.26 ± 4.2</td>
<td>8.44 ± 4.12</td>
<td>0.022</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Timing of procedure</th>
<th>(p) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME1 (h, mean ± SD)</td>
<td>3.2 ± 2.9</td>
</tr>
<tr>
<td>TIME2 (min, mean ± SD)</td>
<td>87.04 ± 54.4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chest tube output</th>
<th>(p) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>before UT (mL, mean ± SD)</td>
<td>1,627 ± 592.15</td>
</tr>
<tr>
<td>Field CPR (n, %)</td>
<td>4/25 (16%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ICU therapeutic management</th>
<th>(p) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packed cells (units, mean ± SD)</td>
<td>4.04 ± 3.6</td>
</tr>
<tr>
<td>Fresh frozen plasma (units, mean ± SD)</td>
<td>3.2 ± 3.29</td>
</tr>
<tr>
<td>Vasopressors' use (n, %)</td>
<td>7/25 (28%)</td>
</tr>
<tr>
<td>Positive balance 24H (mL, mean ± SD)</td>
<td>5,521.73 ± 3,997.26</td>
</tr>
<tr>
<td>Positive balance DIS (mL, mean ± SD)</td>
<td>11,042.63 ± 10,432.6</td>
</tr>
<tr>
<td>Chest tube drainage length (days, mean ± SD)</td>
<td>4.04 ± 2.19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>(p) Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-ICU mortality (n, %)</td>
<td>4 (16%)</td>
</tr>
<tr>
<td>Length of ICU stay (days, mean ± SD)</td>
<td>11 ± 2.3</td>
</tr>
<tr>
<td>LOS (days, mean ± SD)</td>
<td>18.6 ± 7.8</td>
</tr>
</tbody>
</table>

Abbreviations: APACHE, Acute Physiology and Chronic Evaluation; CPR, cardiopulmonary resuscitation; CT, computed tomography; DIS, discharge; ED, emergency department; H, hour; HR, heart rate; ICU, intensive care unit; ISS, Injury Severity Score; LOS, length of hospital stay; SD, standard deviation; SPB, systolic blood pressure; UT, urgent thoracotomy.

*\(p\) value has been considered to be statistically significant if <0.05.

**Indications for UT were described in the Methods section (see above).

†HR-ED, SBP-ED and body temperature at admission to the ED.

‡HR-UT, SBP-UT, \(p\) arterial blood laboratory parameters at the end of UT.

§TIME1 = (hours) from admission to ICU to UT.

‖TIME2 = Duration of UT (total time between transport to the OR and return to the ICU post-UT).

*Total chest tube output during the ICU stay prior to UT.

**Vasopressors during the first 24 hours of ICU stay.

††Total positive balance includes both crystalloid fluids and blood products (PCs and FFPs) at the first 24 hours of the ICU stay and on discharge from the ICU.

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in-hospital mortality in the study population: a high ISS >40; an APACHE score of >30; a prolonged duration of UT; a low body temperature on admission to the ED; low arterial blood pH and bicarbonate level and high arterial lactate level at the end of UT; and use of vasopressors during the first 24 hours of ICU stay.

There were also differences in mortality rates that were associated with the amount of packed red blood cell units administered (p = 0.06), the heart rate on admission to the ED (p = 0.06), and the number of patients who underwent on-site CPR (p = 0.07); however, none of these parameters reached statistical significance (Table 3).

**Discussion**

The main purpose and the focus of our study was cohort of chest trauma patients who underwent an UT. There are some suggestions in literature that indications, therapeutic strategies, and subsequent patients’ clinical outcome might be different after EDT.

In the present study, we retrospectively analyzed severe trauma patients with penetrating and blunt chest injuries who underwent UT. We demonstrated a higher ICU mortality after UT among the patients with blunt chest injuries compared with those with penetrating injuries.

A UT is defined as a thoracotomy performed within the first 48 hours of thoracic injury. There are only few reports in the recent literature which focus on UT experience.

The main indications for UT include damage control surgery (high chest tube output), cardiac tamponade, and need for

### Table 2 Intra-operative findings at thoracotomy

<table>
<thead>
<tr>
<th>Source of bleeding</th>
<th>Penetrating Group</th>
<th>Blunt Group</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lung</td>
<td>15 (60%)</td>
<td>18 (90%)</td>
<td>0.02</td>
</tr>
<tr>
<td>Intercostal artery</td>
<td>7 (28%)</td>
<td>5 (25%)</td>
<td>0.43</td>
</tr>
<tr>
<td>Internal mammary artery</td>
<td>3 (12%)</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Cardiac</td>
<td>3 (11.5%)</td>
<td>0</td>
<td>NA</td>
</tr>
<tr>
<td>Other injuries</td>
<td></td>
<td></td>
<td>0.2</td>
</tr>
</tbody>
</table>

Tracheobronchial injury 2 (8%) 1 (5%) 0.2

**Abbreviation:** NA, not applicable.

### Table 3 In-ICU mortality: univariate analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Survival (n = 32)</th>
<th>Non-survival (n = 13)</th>
<th>p Value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years (mean ± SD)</td>
<td>30.9 ± 13.18</td>
<td>28.76 ± 12.77</td>
<td>0.62</td>
</tr>
<tr>
<td>Gender (male) (%)</td>
<td>26 (81.2%)</td>
<td>10 (76.9%)</td>
<td>0.7</td>
</tr>
<tr>
<td>Blunt thoracic trauma (n, %)</td>
<td>11 (34.4%)</td>
<td>9 (69.2%)</td>
<td>0.036*</td>
</tr>
<tr>
<td>ISS (units, mean ± SD)</td>
<td>27.6 ± 14.3</td>
<td>42.15 ± 19.2</td>
<td>0.009*</td>
</tr>
<tr>
<td>APACHE (units, mean ± SD)</td>
<td>25.9 ± 4.5</td>
<td>31.58 ± 4.5</td>
<td>0.001*</td>
</tr>
<tr>
<td>TIME2 (min, mean ± SD)*</td>
<td>64.03 ± 33.1</td>
<td>141.08 ± 80.07</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>HR-ED (b/min, mean ± SD)</td>
<td>108.4 ± 16.4</td>
<td>122.5 ± 18.8</td>
<td>0.06</td>
</tr>
<tr>
<td>SBP-ED (mmHg, mean ± SD)</td>
<td>77 ± 24.9</td>
<td>57.4 ± 17.5</td>
<td>0.04*</td>
</tr>
<tr>
<td>Body temperature-ED (°C, mean ± SD)</td>
<td>36.5 ± 1.48</td>
<td>32.9 ± 2.02</td>
<td>0.001*</td>
</tr>
<tr>
<td>Lactate arterial blood (mmol/L, mean ± SD)</td>
<td>3.44 ± 2.3</td>
<td>9.5 ± 5.2</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Bicarbonate arterial blood (mmol/L, mean ± SD)</td>
<td>21.38 ± 3.3</td>
<td>16.1 ± 4.67</td>
<td>0.002*</td>
</tr>
<tr>
<td>pH, arterial</td>
<td>7.29 ± 0.07</td>
<td>7.1 ± 0.15</td>
<td>0.004*</td>
</tr>
<tr>
<td>Chest tube output (mL, mean ± SD)</td>
<td>1,637.5 ± 707.6</td>
<td>1,875 ± 527.64</td>
<td>0.31</td>
</tr>
<tr>
<td>Packed balance 24H (mL, mean ± SD)</td>
<td>3.53 ± 2.6</td>
<td>6.46 ± 4.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Positive balance 24H (mL, mean ± SD)</td>
<td>6,290 ± 581.1</td>
<td>6,858.3 ± 446.18</td>
<td>0.77</td>
</tr>
<tr>
<td>On-site CPR (n, %)</td>
<td>7 (21.9%)</td>
<td>7 (53.8%)</td>
<td>0.07</td>
</tr>
<tr>
<td>Vasopressors’ use (n, %)</td>
<td>7 (21.9%)</td>
<td>8 (61.5%)</td>
<td>0.016*</td>
</tr>
</tbody>
</table>

**Abbreviations:** APACHE, Acute Physiology and Chronic Evaluation; CPR, cardiopulmonary resuscitation; DIS, discharge; ED, emergency department; EDT, emergency department thoracotomy; FFP, fresh frozen plasma; HR, heart rate; ICU, intensive care unit; ISS, Injury Severity Score; PC, packed red cells; SD, standard deviation; SPB, systolic blood pressure; UT, urgent thoracotomy.

*Length of procedure (EDT).

HR-ED, SBP-ED, and body temperature on admission to the ED.

Labatory parameters at the end of (UT).

Total chest tube output prior to UT.

Overall amount of packed red blood cells units administered during the first 24 hours of the ICU stay.

Total positive balance includes both crystalloid fluids and blood products (PCs and FFPs) at the first 24 hours of ICU stay.

*p Value has been considered to be statistically significant if less than 0.05.
tracheobronchial repair (as evidenced by a persistent air leak through a thoracic tube).\textsuperscript{1,5,9} All of these are well recognized as indications for UT in both penetrating and blunt chest trauma.\textsuperscript{5} Onat et al\textsuperscript{4} reported a series in which only \textasciitilde{}14% of patients with penetrating thoracic injuries underwent UT. In their study, the main indications for UT were high initial chest tube output, high ongoing output, shock (systolic blood pressure \textasciitilde{}90 mm Hg), signs of pericardial tamponade, radiographic signs of a large hemothorax, and massive air leak. Similarly, our experience at Soroka Medical Center over the last decade has been that \textasciitilde{}16% of all patients presenting with penetrating thoracic trauma underwent an UT in the OR during their hospital stay. In contrast, Karmy-Jones et al\textsuperscript{10} reported that 22% of blunt and 42% of their penetrating thoracic trauma patients underwent UT for thoracic hemorrhage.\textsuperscript{5} In the current study, we retrospectively analyzed the hospital records of 45 trauma patients with predominant thoracic penetrating and blunt injuries who underwent UT during the first 48 hours of their ICU stay. The main indications for UT in our study were similar to those in previously published reports.\textsuperscript{4, 5} The overall mortality rate in the current study was 29% (comprised of 30% mortality among the patients with penetrating trauma and 60% mortality among the blunt trauma patients). These findings correlate well with the data published by Karmy-Jones et al (29%).\textsuperscript{5} In contrast, Onat et al\textsuperscript{4} described an overall mortality rate of only 10.8% in patients with penetrating thoracic trauma. The causes of death in the current study were sepsis and coagulopathy followed by multiple organ failure. This finding correlates well with previously published findings.\textsuperscript{4, 5}

In the current study, the following parameters were found to be significant risk factors for ICU mortality on univariate analysis: a high ISS (\textasciitilde{}40); an APACHE score of \textasciitilde{}30; the mechanism and the severity of the trauma; the body temperature on arrival at the ED; the pH, bicarbonate, and lactate values in the arterial blood at the end of the procedure; the duration of the procedure; and the use of vaspressors after UT.

In previously published data, a high ongoing chest tube output and concomitant abdominal, pelvic, and diaphragmatic trauma were found to correlate with poor clinical outcomes.\textsuperscript{5, 7} Although also in the present study both groups of patients had other injuries, these were minor and clinically insignificant. In our study, we did not find a difference in the chest tube output between the blunt and penetrating trauma groups. This finding might be explained by the short period of time that elapsed prior to UT in our patients. The time interval to UT following ICU admission in our study was 3.2 \textpm{} 2.9 hours in the patients who sustained penetrating chest trauma vs 2.35 \textpm{} 1.89 hours in the patients with blunt chest trauma. In contrast, the duration of the UT procedure itself was demonstrated to be a significant risk factor for ICU mortality. Taking into account all aspects of elapsed time both before and during UT, there appears to be a case for performing UT as soon as possible, and also for limiting the procedure to damage control alone so as to minimize the time spent by the patients in the OR.

Patients with high risk factors for ICU mortality might be managed non-operatively (arterial embolization or bronchial occlusion, quick intrathoracic clamp or packing, and leaving cavity open, etc.).

Onat et al\textsuperscript{4} also reported a high ISS score as a contributory risk factor for mortality in patients with penetrating thoracic injuries. Interestingly, the same authors\textsuperscript{5} found that a high number of transfused blood units correlated with a high mortality rate in patients with penetrating thoracic injuries. In the present study, the number of administered packed red blood cell units differed between survivors and non-survivors (3.53 \textpm{} 2.6 vs 6.46 \textpm{} 4.7). However, this parameter was not found to be statistically significant ($p = 0.06$). Laboratory signs of acidosis and hypothermia at the end of UT were found to be risk factors for ICU mortality in our study. Those findings are known well from previously published data on the general multiple trauma population\textsuperscript{10} and are related to the “triade of death” in trauma: acidosis, hypothermia, and coagulopathy. In view of this finding, it seems to be extremely important to optimize these laboratory parameters prior to the procedure, especially if there is sufficient time to do so.

Our study has several important limitations: It is retrospective and single-center; it incorporates only a small number of patients; and by virtue of being retrospective, the data at our disposal was limited to the available documentation in the patient’s hospital records. Furthermore, multivariate analysis was not performed because of small number of samples.

**Conclusion**

We demonstrated a higher mortality rate after UT in patients with blunt chest trauma patients than in patients with penetrating chest trauma. Our findings suggest that UT should be performed in both penetrating and blunt chest trauma as quickly as practically possible and should be limited to damage control and to stop active bleeding to minimize the duration of the procedure. It also emerges that acidosis and hypothermia in patients with predominant chest trauma should be treated extremely aggressively before, during, and after UT.

**Conflict of Interest**

The authors declare no conflict of interest.

**Ethics**

The Human Research and Ethics Committee at Soroka Medical Center in Beer-Sheva, Israel, approved this study (RN-0124–15-SOR).

**Authors’ Contributions**

Dr. Yael Refaely participated in the study design, data collection, data analysis, data interpretation, and writing. Dr. Leonid Koyfman participated in the literature search, study design, data collection, data analysis, and data interpretation. Prof. Michael Friger participated in data collection and performed the statistical analysis and data interpretation. Dr. Leonid Ruderman participated in the design of the study, performed the statistical analysis, and helped in revising the manuscript. Dr. Mahmud Abu Saleh participated in the design of the study, performed the statistical analysis, and helped in revising the manuscript. Dr. Gidon Sahar participated in the design of the study, performed the statistical analysis, and helped in revising...
the manuscript. Dr. Gad Shaked participated in the design of the study, performed the statistical analysis, and helped in revising the manuscript. Dr. Moti Klein conceived the study, participated in its design and coordination, and helped to draft the manuscript. Dr. Evgeni Brotfain participated in the design of the study and coordination and helped to draft the manuscript. All authors read and approved the manuscript. It is important to clarify that all authors listed agreed that both Dr. Refaely and Dr. Koyfman contributed equal work regarding the paper. They both participated in design, data collection, analysis, interpretation, and writing of the paper.

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