Can External Signs of Trauma Guide Management?

Lessons Learned From Suicide Bombing Attacks in Israel

Gidon Almogy, MD; Tal Luria, MD; Elihu Richter, MD, PhD; Reuven Pizov, MD; Tali Bdolah-Abram, MSc; Yoav Mintz, MD; Gideon Zamir, MD; Avraham I. Rivkind, MD, FACS

Background: Following a suicide bombing attack, scores of victims suffering from a combination of blast injury, penetrating injury, and burns are brought to local hospitals.

Objective: To identify external signs of trauma that would assist medical crews in recognizing blast lung injury (BLI) and effectively triaging salvageable and non-salvageable victims.

Design: Retrospective analysis of all 15 suicide bombing attacks that occurred in Israel from April 1994 to August 1997.

Setting: National survey.

Patients: One hundred fifty-three victims died and 798 were injured as a result of 15 attacks. Medical records were reviewed for external signs of trauma, such as burns and penetrating injuries, and the presence of BLI.

Main Outcome Measure: The odds ratio for BLI and death.

Results: Three settings were targeted: buses, semiconfined spaces, and open spaces. Sixty survivors (7.5%) suffered from BLI, which was more common in buses (37 of 260) than semiconfined spaces (14 of 279) and open spaces (9 of 259) (P<.001). Victims with BLI were more likely to suffer from penetrating injury to the head or torso, burns covering more than 10% of the body surface area, and skull fractures (odds ratios, 4, 11.6, and 55.8, respectively; P<.001). Victims who died at the scene were more likely to suffer from burns, open fractures, and amputations in comparison with survivors (odds ratios, 6.5, 18.6, and 50.1, respectively; P<.001).

Conclusions: Following a suicide bombing attack, external signs of trauma should be used to triage victims to the appropriate level of care both at the scene and in the hospital. Triage of salvageable and nonsalvageable victims should take into account the presence of amputations, burns, and open fractures.

Arch Surg. 2005;140:390-393

In the last decade, there has been a dramatic increase in the number and extent of suicide attacks that target the civilian population. Although the concept of the suicide attacker is not new, we have recently evidenced the lethal effects of the ability of a suicide bomber to detonate a relatively large load of explosive material in proximity to his or her victims. The combination of military-grade explosive material, high-mass shrapnel, and precise control of the timing of detonation has transformed suicide bombing attacks into an ultimate tool in the hands of terrorists. Detonation of an explosive material causes injuries in 4 principal mechanisms. Primary blast injury is caused by the rapid outward spread of the shock wave, the energy of which is inversely proportional to the distance from the explosion's epicenter. Gas-containing organs such as the lung, tympanic membrane, and bowel are most often injured. Secondary blast injury is caused by penetrating missiles composed of bomb-based material (shrapnel) and debris that are propelled by the shock wave. Tertiary blast injuries result from a victim's body being displaced by expanding gasses and high winds; trauma then occurs from tumbling and impacting objects. Burns and associated injuries from the collapse of buildings are defined as quaternary injuries and are also common among survivors of explosions. Blast lung injury (BLI) is caused by the rapid spread of the shock wave, a phenomenon that is exacerbated in confined spaces. Victims of suicide bombing attacks inside buses have been shown to suffer from diffuse alveolar injury, bilateral pneumothoraces, and bronchopleural fistulas. Timely initiation of therapy, in-
cluding unconventional methods such as high-frequency jet ventilation, independent lung ventilation, and nitric oxide, may improve survival. Early recognition of BLI, a leading cause of in-hospital mortality, may improve outcome by directing patients to the appropriate level of care and initiating early treatment.

We have recently analyzed the experience acquired in a Level I trauma center in managing and treating survivors of suicide bombing attacks. Because of several mostly nonmedical factors, the majority of severely injured casualties in Israel are currently being evacuated to the nearest medical facility and not to a Level I trauma center. The objective of this work was to identify risk factors for BLI, which mandates an experienced and well-equipped facility to provide advanced modes of ventilation and supportive care. We also studied risk factors for mortality at the scene to limit the number of nonsalvageable victims who are evacuated from the scene and consequently to provide maximal treatment to salvageable patients.

METHODS

We retrospectively collected data on all 15 suicide bombing attacks that took place in Israel between April 1994 and August 1997. Hospital records and trauma registry records were retrieved from the 13 different hospitals in which the victims were treated. Records were reviewed for demographic data such as age, sex, attack setting, and survival; the presence of BLI; the presence of tympanic membrane rupture; the presence and location of penetrating injuries; the presence and extent of burns; and the presence and location of fractures.

Blast lung injury was defined as hypoxemia (\(\text{PaO}_2/\text{FiO}_2\) < 200) and the presence of typical imaging findings on chest x-ray film, such as unilateral or bilateral pulmonary infiltrates. Because of the high incidence of tympanic membrane trauma following blast injury, all patients were examined by teams from the ear, nose, and throat department. Two thresholds were set for patients with burns, based on the likelihood that they would be easily identified. Emergency medical services crews working at the scene of an attack require easily identifiable signs of trauma, and therefore the threshold of burns covering more than 30% of the body surface area (BSA) was set. For emergency department crews, the threshold was lowered and set at burns covering more than 10% of the BSA.

Forensic data were retrieved from the Israeli Center for Forensic Medicine in Abu Kabir. The extent of external injuries was recorded in every case. Postmortem examinations were performed on a minority of the victims. We therefore chose to analyze only descriptive data of external injuries such as amputations, burns, and open fractures.

Data are presented as median and range. The \(\chi^2\) test and Fisher exact test were used to compare proportions between the different groups. The odds ratio as well as its 95% confidence interval were calculated for each of the injury types studied. A \(P\) value ≤ .05 was considered statistically significant. Statistical analysis was performed using SPSS version 11.5 (Statistical Package for the Social Sciences, Chicago, Ill).

RESULTS

One hundred fifty-three victims died and 798 were injured in 15 suicide bombing attacks that took place in Israel between April 1994 and August 1997 (Table 1). The targets were buses (n=6), semiconfined spaces (SCS) such as restaurants and covered open spaces (n=5), and open spaces (OS) such as bus stops and street cafés (n=4). The fatality-casualty ratios were 95:355 (26.7%), 25:304 (9.0%), and 33:292 (11.3%), respectively (\(P<.001\), buses vs SCS and OS). The incidence of BLI was higher in buses but not in SCS (buses, 13.2% vs SCS, 4.5% and OS, 3%, \(P<.001\)). The incidence of tympanic membrane rupture was significantly higher in buses and SCS than in OS (buses, 13.1% and SCS, 11.8% vs OS, 2.3%, \(P<.001\)).

LOCATION OF PENETRATING WOUNDS

The head was the most common site of penetrating injury among survivors who were inside a bus, the limbs were the most common site in SCS, and the torso was the most common site of penetrating injury in OS (Figure 1A). After correcting for the relative BSA of each region of the body, the head was the most common site of penetrating injury among survivors in all settings (Figure 1B).

Table 1. Demographic Data for All 15 Suicide Bombing Attacks in Israel, April 1994 to August 1997

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Median (Range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of attacks</td>
<td>15</td>
</tr>
<tr>
<td>Age of victims</td>
<td>38 y (3 weeks to 85 y)</td>
</tr>
<tr>
<td>Casualties/attack</td>
<td>61.5 (23-168)</td>
</tr>
<tr>
<td>Wounded/attack</td>
<td>44.3 (5-155)</td>
</tr>
<tr>
<td>Fatalities/attack</td>
<td>9.5 (2-25)</td>
</tr>
</tbody>
</table>

Figure 1. Schematic reconstruction of the suicide bombing attack on the No. 18 bus in Jerusalem. Lateral view (left) and top view (right). Some of the passengers were shielded from the blast by other passengers or by the configuration of the seats (left).
To study the odds ratio for BLI among survivors, we analyzed the following parameters: the presence of penetrating wounds to the head, torso, and limbs; the presence of burns covering more than 10% of the BSA; the presence and location of fractures; and the presence of tympanic membrane rupture. The majority of patients with penetrating wounds to the torso also suffered from penetrating wounds to the head (58 of 71 patients with penetrating wounds to the torso also suffered from penetrating wounds to the head, compared with 26 of 64 patients with penetrating wounds to an extremity). We therefore combined patients with penetrating injury to the head or torso and compared them with patients with penetrating injury to the extremities. Likewise, patients with skull or facial fractures were compared with patients with extremity fractures. Blast lung injury was significantly more common in survivors who had skull and facial fractures, burns covering more than 10% of the BSA, and penetrating wounds to the head or torso (Table 2).

### Table 2. Univariate Analysis of the Relationship Between External Signs of Trauma and the Occurrence of Blast Lung Injury (BLI)*

<table>
<thead>
<tr>
<th>Sign of Trauma</th>
<th>Survivors With BLI (n = 60)</th>
<th>Survivors Without BLI (n = 738)</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penetrating wounds to head or torso (n = 77)</td>
<td>16 (26.7)</td>
<td>61 (8.3)</td>
<td>4.0 (2.2-7.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Penetrating wounds to extremities (n = 64)</td>
<td>6 (10.0)</td>
<td>58 (7.6)</td>
<td>1.3 (0.7-2.9)</td>
<td>.30</td>
</tr>
<tr>
<td>Burns covering more than 10% of the body surface area (n = 25)</td>
<td>11 (18.3)</td>
<td>14 (1.9)</td>
<td>11.6 (5.0-26.9)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Tympanic membrane rupture (n = 73)</td>
<td>6 (10.0)</td>
<td>67 (9.1)</td>
<td>1.1 (0.6-1.9)</td>
<td>.76</td>
</tr>
<tr>
<td>Skull fractures (n = 18)</td>
<td>14 (23.3)</td>
<td>4 (0.5)</td>
<td>55.8 (17.7-176.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Extremity fractures (n = 105)</td>
<td>8 (13.3)</td>
<td>97 (13.1)</td>
<td>1.0 (0.5-2.2)</td>
<td>.99</td>
</tr>
</tbody>
</table>

*Data are presented as number (percentage) of patients unless otherwise indicated.

### Table 3. Univariate Analysis of the Relationship Between External Signs of Trauma and Mortality at the Scene, According to Attack Setting*†‡

<table>
<thead>
<tr>
<th>Sign of Trauma</th>
<th>All Attacks</th>
<th>Attacks Inside Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dead (n = 153)</td>
<td>Wounded (n = 798)</td>
</tr>
<tr>
<td>Open fractures (n = 70)</td>
<td>56 (36.6)</td>
<td>24 (3.0)</td>
</tr>
<tr>
<td>Amputations (n = 74)</td>
<td>63 (41.2)</td>
<td>11 (1.3)</td>
</tr>
<tr>
<td>Burns‡ (n = 178)</td>
<td>75 (49.0)</td>
<td>103 (12.9)</td>
</tr>
</tbody>
</table>

*Data are presented as number (percentage) of patients unless otherwise indicated.
†P<.001.
‡All patients with burns.

**SIGNS OF TRAUMA AND BLI**

To study the odds ratio for BLI among survivors, we analyzed the following parameters: the presence of penetrating wounds to the head, torso, and limbs; the presence of burns covering more than 10% of the BSA; the presence and location of fractures; and the presence of tympanic membrane rupture. The majority of patients with penetrating wounds to the torso also suffered from penetrating wounds to the head (58 of 71 patients with penetrating wounds to the torso also suffered from penetrating wounds to the head, compared with 26 of 64 patients with penetrating wounds to an extremity). We therefore combined patients with penetrating injury to the head or torso and compared them with patients with penetrating injury to the extremities. Likewise, patients with skull or facial fractures were compared with patients with extremity fractures. Blast lung injury was significantly more common in survivors who had skull and facial fractures, burns covering more than 10% of the BSA, and penetrating wounds to the head or torso (Table 2).

**SIGNS OF TRAUMA AND MORTALITY**

Burns were common both in the dead and in survivors (Table 3). The presence of amputations, open fractures, and burns was significantly greater in fatally injured victims than in survivors, regardless of the attack setting (Table 3). These findings were even more prominent among casualties in buses. Only 2 of 41 victims who suffered from traumatic amputations inside a bus survived the blast; all 19 victims who suffered from burns covering more than 30% of the BSA inside a bus died of their wounds; and only 4 of 25 victims with open fractures who were injured inside a bus survived the blast.

**COMMENT**

The present signs point to the suicide bomber as a growing threat to civilians all over the world. Our mission as physicians is to minimize the fatality rate of such attacks and improve the quality of life for survivors. Rapid evacuation of salvageable victims and swift recognition of life-threatening injuries will enable us to optimize utilization of our limited resources and provide optimum care to our patients.

Following a suicide bombing attack, numerous victims are brought into the emergency department suffering from a combination of multi-organ injuries caused by the blast, penetrating injuries caused by shrapnel and other debris, and burns. In the initial phases, the signs and symptoms of BLI may be subtle and are often underestimated.11 The conditions of patients with BLI, however, quickly deteriorate and they often require sophisticated modes of mechanical ventilation such as high-frequency jet ventilation and 1-lung ventilation.10 The cardinal finding of this study is that by evaluating the degree of external trauma we can anticipate the risk of BLI, an important factor in patient survival after a suicide bombing attack.10,13 Early recognition of patients at high risk for BLI may improve the delivery of treatment and overall survival by initiating appropriate treatment at centers with higher levels of care, ie, medical facilities with...
level I trauma units and well-experienced, trained, and equipped intensive care unit crews.

Our results show that patients with skull fractures, burns covering more than 10% of the BSA, and penetrating injuries to the head or torso are more likely to suffer from BLI. A possible explanation for these findings is shown in Figure 1. Partitions and even other victims can offer some protection from the effects of the blast wave, penetrating missiles, and burns. Since the explosive device is usually carried on the upper back or chest of the attacker, it is likely that victims in the closest circle absorb high-energy penetrating missiles to the bulky midportion of their bodies, i.e., the head and/or torso. Victims at farther ranges are partially protected by partitions (bus) and by the bodies of other victims (all settings) and are therefore more likely to sustain penetrating injury to the extremities and less likely to suffer from penetrating injury to the head or torso.

The large numbers of dead and injured, the familiar locations of everyday life, and the threat of second-hit attacks add to the confusion at the scene of a suicide bombing attack.14 Emergency medical services crews are faced with a desperate situation, and speedy decisions need to be made.15,16 Level of consciousness and the presence of signs of life, such as pulse and blood pressure, are difficult to assess in these chaotic circumstances. Our results show that by defining easily recognizable external signs of trauma, such as amputations, open fractures, and burns covering more than one third of the BSA, emergency medical services crews may be better able to distinguish salvageable from nonsalvageable casualties and as a result optimize evacuation preferences. Furthermore, these results may serve to guide triage to either level I trauma centers or non–level I medical centers (Figure 2).

The distance of the victim from the explosion determines the amount of energy and penetrating missiles that are absorbed by the victim and is the most important factor influencing survival.6,7 Our findings and the findings of others suggest that survival is also affected by the physical configuration of the scene.8 Factors such as the location of the victim within the scene and the presence of a physical partition, such as the back of a seat, also influence survival (Figure 1). Simple measures such as elevating the backs of the seats to protect the head, keeping some windows open to decrease reflection of the blast wave, and limiting the number of passengers to the number of seats and thus preventing standing inside the bus may decrease the fatality rate. Implementing some of these measures is possible in other settings such as restaurants, cafes, and open markets, but this would entail a more profound effect on everyday life.

To summarize, the presence of burns, skull fractures, and penetrating injury to the head or torso among survivors are markers of proximity to the center of the blast and are associated with BLI. Easily recognizable external signs of trauma may assist emergency crews at the scene by differentiating salvageable from nonsalvageable patients. These findings may help overcome the chaos at the scene of an explosion and at the admitting hospital by limiting the number of nonsalvageable victims who reach the hospital and by directing those with severe lung injury to level I trauma centers.

Accepted for Publication: December 15, 2004.
Correspondence: Avraham I. Rivkind, MD, FACS, Department of Surgery, Hebrew University–Hadassah Medical Center, PO Box 12000, Jerusalem 91120, Israel (rivkind@cc.huji.ac.il).
Author Contributions: Drs Almogy and Luria contributed equally as first coauthors.

REFERENCES

14. Frykberg ER. Medical management of disasters and mass casualties from terrorist bombings: how can we cope? J Trauma. 2002;53:201-212.