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The ins and outs of terrorist bus explosions: Injury profiles of on-board explosions versus explosions occurring adjacent to a bus

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ABSTRACT

Background: Terrorist explosions occurring in varying settings have been shown to lead to significantly different injury patterns among the victims, with more severe injuries generally arising in confined space attacks. Increasing numbers of terrorist attacks have been targeted at civilian buses, yet most studies focus on events in which the bomb was detonated within the bus. This study focuses on the injury patterns and hospital utilisation among casualties from explosive terrorist bus attacks with the bomb detonated either within a bus or adjacent to a bus.
Methods: All patients hospitalised at six level I trauma centres and four large regional trauma centres following terrorist explosions that occurred in and adjacent to buses in Israel between November 2000 and August 2004 were reviewed. Injury severity scores (ISS) were used to assess severity. Hospital utilisation data included length of hospital stay, surgical procedures performed, and intensive care unit (ICU) admission.
Results: The study included 262 victims of 22 terrorist attacks targeted at civilian bus passengers and drivers; 171 victims were injured by an explosion within a bus (IB), and 91 were injured by an explosion adjacent to a bus (AB). Significant differences were noted between the groups, with the IB population having higher ISS scores, more primary blast injury, more urgent surgical procedures performed, and greater ICU utilisation. Both groups had percentages of nearly 20% for burn injury, had high percentages of injuries to the head/neck, and high percentages of surgical wound and burn care.
Conclusions: Explosive terrorist attacks detonated within a bus generate more severe injuries among the casualties and require more urgent surgical and intensive level care than attacks occurring adjacent to a bus. The comparison and description of the outcomes to these terrorist attacks should aid in the preparation and response to such devastating events.

Introduction

Over the past several decades the world has experienced a surge of terrorist attacks targeted towards civilians, which often result in mass casualty incidents (MCI). Victims of these terror attacks are susceptible to many of the various types of trauma injuries, thereby creating highly complex patterns of injury.[1–4] As each attack has been unique with regards to the type and weight of explosive, the setting, time of day, the targeted population, the crowdedness, and more, it has proved a challenging task to compare the injury patterns arising from the different attacks.[5–8] Further, injury characteristics of terrorist attacks differ significantly from common civilian trauma in that there are more penetrating and blast injuries following terrorist attacks.[9,10]

Outdoor attacks have been shown to have different mortality rates and injury patterns from confined space explosions.[11–16] This has been attributed largely to the physics of a confined space explosion, in which the blast waves generated will deflect off a solid structure, thereby amplifying the lethal effect of the blast wave.[17] Bus attacks are a curious occurrence given the composition of the bus and the density at which people are situated. Leibovici et al.[18] found that explosions in buses had increased mortality rates, greater incidence of primary blast injuries, and caused more severe injuries among survivors than outdoor explosions. Kosashvili et al.[21] examined outcomes from terrorist bomb explosions and found bus attacks to have higher immediate mortality rates, different injury severity distributions, and a different array of surgical procedures performed on victims as compared to explosions in indoor or outdoor settings.

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What has been increasingly occurring are multitudes of attacks directed at civilian buses, and these attacks have occurred both within buses and adjacent to them. The literature commonly refers to all bus explosions as one situation, while in fact there may exist unique differences. To date there have been numerous papers describing injury patterns caused by explosions, yet there exist few large peer-reviewed studies describing injury patterns from terror explosions that occur within buses, nor has there been any comparison of terrorist explosions that have occurred within a bus or adjacent to a bus.

Because a blast wave is amplified in a confined space, we hypothesised that injuries would be more severe in explosions occurring within the bus. We hereby describe and compare the injury patterns associated with a series of 22 terrorist bombings in Israel involving buses that occurred between November 2000 and August 2004.

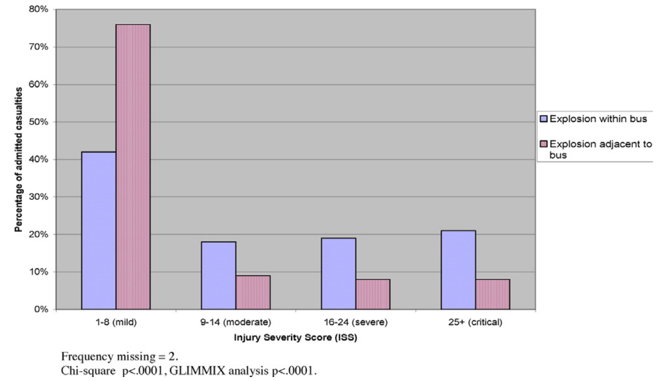

Fig. 1. Injury severity among victims of explosions occurring within a bus versus adjacent to a bus. Frequency missing = 2; Chi-square $p < 0.0001$, GLIMMIX analysis $p < 0.0001$.

Materials and methods

Mass casualty incidents (MCI) resulting from terrorist explosions that occurred in and in vicinity to buses in Israel between November 2000 and August 2004 were reviewed. These dates span the period of the 2nd Intifada, during which Israel experienced a surge of terrorist attacks. Data were obtained from the Israel National Trauma Registry (ITR), maintained by Israel's National Center for Trauma and Emergency Medicine Research at the Gertner Institute for Epidemiology and Health Policy Research.

We analysed the clinical characteristics of patients registered on the ITR with "explosion" listed as cause for hospitalisation. We included all patients who were passengers/bus drivers and were injured in any of 22 terrorist explosions involving buses. We excluded bystanders who were injured in the explosion. Data is collected on victims of trauma who were hospitalised, died in the emergency department, or who were transferred to another hospital. The ITR does not collect data on individuals who were dead in scene or upon arrival, nor does it follow patients after discharge to home from the emergency department. Data are recorded by trained medical registrars at each hospital and electronic files are transferred to the ITR.

During this period, the ITR included trauma patients admitted to all six level I trauma centres and four large regional trauma centres in Israel. The ITR contains demographic and clinical data, including the nature and mechanism of trauma, various injury severity indices, pre-hospital and in-hospital evaluation, medical diagnosis and initial treatment, medical management, and outcome. An injury severity score (ISS) was used to assess severity. Body regions were categorised based on the six regions used for computing the ISS from the abbreviated injury scoring (AIS). Hospital utilisation data included length of hospital stay (LOS), surgical procedures performed, and intensive care unit (ICU) admission.

Statistical analysis was performed using the SAS statistical software version 9.2 (SAS, Cary, NC). As the injuries in any attack have a tendency to show clustering (more similar injuries within attacks than between attacks), the assumption of independence that underpins the usual chi-squared test is not satisfied. Analysis with PROC GLIMMIX in SAS allows for this clustering (by using a variable identifying the attack fitted as a random effect) but performs unreliably with small numbers. Thus significances of differences in both analyses are shown and are interpreted conservatively. A p value less than 0.05 was considered statistically significant; all p values are two-tailed.

Results

We analysed 22 terrorist attacks targeted at civilian buses between November 2000 and August 2004. Sixteen of these explosions occurred within a bus (IB) and generated 171 victims, and six of these attacks occurred adjacent to a bus (AB) and generated 91 casualties. A total of 262 patients were admitted to the 10 trauma centres participating in the Israel National Trauma Registry.

ISS scores of the two patient populations can be seen in Fig. 1. The IB victims were significantly more severely injured than the AB cohort, as 40% of the IB victims had an ISS $\geq$ 16, while 16% of the AB population had ISS $\geq$ 16. 46% of the IB population had three or more body regions affected, while 30% of the AB population sustained injuries to three or more body regions (Table 1).

The distribution of injuries can be seen in Table 1. IB patients demonstrated significantly more injuries to the face (58% vs. 38%), chest (37% vs. 10%; largely lung contusions), and abdomen (19% vs. 5%). Those victims also presented with higher (though not statistically significant) percentages of severe (AIS $\geq$ 4) head injury, which were mostly cerebral haematomas. In the AB population there were more (significantly by chi-squared test, but not by GLIMMIX) external injuries, which include mild soft tissue injuries and burns, than the IB group (54% vs. 34%).

Table 1
Body region injured and nature of injury among victims of terrorist explosions.

	IB, N = 171 N (%)	AB, N = 91 N (%)	p^*	p^{**}
No. body regions injured			0.014	0.153
1–2	92 (54)	64 (70)		
3+	79 (46)	27 (30)		
Affected body regions[a]				
Head or neck	77 (45)	40 (44)	0.971	0.868
Severe head injury (AIS $\geq$ 4)	23 (13)	5 (5)	0.076	0.059
Face	99 (58)	35 (38)	0.004	0.038
Chest (including lungs)	63 (37)	9 (10)	<0.0001	0.010
Severe chest injury (AIS $\geq$ 4)	32 (19)	2 (2)	0.0003	0.014
Abdomen	33 (19)	5 (5)	0.005	0.009
Severe abdominal injury (AIS $\geq$ 4)	6 (4)	2 (2)	0.834	0.561
Extremities	84 (49)	51 (56)	0.348	0.224
External injuries	58 (34)	49 (54)	0.003	0.242
Nature of injury				
Blunt only	27 (16)	64 (73)	0.0001	0.003
Penetrating only	96 (58)	8 (9)	0.0001	0.0007
Blunt + penetrating	44 (26)	16 (18)	0.180	0.748
Burns	42 (25)	17 (19)	0.353	0.619

AIS, abbreviated injury score; IB, explosion within bus; AB, explosion adjacent to bus.
Head and Neck are considered one region when calculating ISS.
External injuries include abrasions, lacerations, contusions and burns.
[a] Affected individuals may be injured in more than one region.
[*] Assessing distributional differences using χ^2 test with continuity correction.
[**] Assessing distributional differences using GLIMMIX procedure.