Civilian casualties of terror-related explosions: The impact of vascular trauma on treatment and prognosis

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OBJECTIVES: A high prevalence (10%) of vascular trauma (VT) was previously described in terror-related trauma as compared with non–terror-related trauma (1%), in a civilian setting. No data regarding outcome of VT casualties of improvised explosive device (IED) explosions, in civilian settings, are available. The aim of the current study is to present the prognosis of civilian casualties of IED explosions with and without VT.

METHODS: A retrospective analysis of the Israeli National Trauma Registry was performed. All patients in the registry from September 2000 to December 2005 who were victims of explosions were included. These patients were subdivided into patients with VT (n = 109) and non-VT (NVT) (n = 1,152). Both groups were analyzed according to mechanism of trauma, type and severity of injury, and treatment.

RESULTS: Of 1,261 explosion casualties, there were 109 VT victims (8.6%). Patients with VT tended to be more complex, with a higher injury severity score (ISS): 17.4% with ISS 16 to 24 as compared with only 10.5%. In the group of critically injured patients (ISS, 25–75), 51.4% had VT compared with only 15.5% of the NVT patients. As such, a heavy share of hospitals' resources were used—trauma bay admission (62.4%), operating rooms (91.7%), and intensive care unit beds (55.1%). The percentage of VT patients who were admitted for more than 15 days was 2.3 times higher than that observed among the NVT patients. Lower-extremity VT injuries were the most prevalent. Although many resources are being invested in treating this group of patients, their mortality rate is approximately five times more than NVT (22.9% vs. 4.9%).

CONCLUSIONS: Vascular trauma casualties of IED explosions are more complex and have poorer prognosis. Their higher ISS markedly increases the hospital's resource utilization, and as such, it should be taken into consideration either upon the primary evacuation from the scene or when secondary modulation is needed in order to reduce the burden of the hospitals receiving the casualties. (*J Trauma Acute Care Surg.* 2016;81: 435–440. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Prognostic/epidemiologic study, level V.

KEY WORDS: Explosions; improvised explosive device; injury pattern; terror; vascular trauma.

Terrorists' major goals, all over the world, are to maximize the number of casualties and mortality.[1] The use of improvised explosive devices (IEDs) has gained popularity among terrorists because of the ease of manufacture, simplicity of activation, and abundance of determined perpetrators. Most of the bombs used by the terrorists nowadays are embellishment of the ordinary conventional explosive material, achieved by the addition of steel balls, screws, or nails, which increase the impact of the explosion and its lethality.[2,3]

During the early years of the 21st century (2000–2005), Israel was subjected to 151 IED explosions conducted by suicide bombers against the civilian population.[3–12] In addition to the classic manifestations of blunt, penetrating injuries and burns, explosion victims may also present a unique pattern of blast injuries. Projectiles, such as steel balls, nails, screws, and nuts packed around the explosive substance, were frequently used by terrorists in Israel and caused devastating penetrating injuries and increased mortality.[3,8,11–13]

Suicide bombers attacks may generate high (>850 m/s) as well as low velocity of shrapnel injuries secondary to explosions, which could be the cause of both direct and indirect arterial injuries.[13–15] Vascular trauma (VT) constitutes a very substantial part of the previously mentioned injuries, most often threatening the patient's life, extremity viability, or both. The incidence of terror-related VT occurs 10 times more than that of non–terror-related VT.[15]

The current information regarding the outcome of IED explosions reflects data of the injuries found in armed troops wearing military protective gear, such as ballistic-proof vests and helmets, and frequently travelling in armored vehicles.[16–23] The aim of the current study is to present the impact of VT and non-VT (NVT) on the prognosis of civilian casualties of IED explosions.

METHODS

A retrospective analysis of the Israeli Trauma Registry, gathered by the National Center for Trauma and Emergency Medicine Research in Gertner Institute, Tel Hashomer, Ramat Gan, Israel, was performed. At the time of the analysis, the Israeli trauma registry was based on information gathered from all six Level I trauma centers in Israel and four large Level II trauma centers, located all over the country. The registry includes all the data regarding hospitalized patients and in-hospital mortality.

Every patient record in the registry is composed of approximately 200 different parameters including demographic data, the circumstances of injury, trauma bay usage, diagnoses (*International Classification of Diseases, Ninth Revision*, Abbreviated Injury Scale), injury severity score (ISS), procedures performed, intensive care unit (ICU) admission, hospitalization length of stay (LOS), and outcome.

All patients registered from September 2000 to December 2005 were included in this analysis. The focus of our interest was the group of patients who were injured by terror explosions. This group of patients was subdivided into patients with or without vascular injuries. Both subgroups were analyzed according to the type of trauma, severity of injury, and treatment. Vascular injuries were defined as diagnosis of injury to blood vessels according to the *International Classification of Diseases, Ninth Revision* (900–904), or injury to vessels according to the AIS diagnosis.

Statistical analysis was performed using SAS (SAS version 9.1.3; SAS Institute Inc., Cary, NC) and was mainly based on descriptive statistics and group comparisons. Statistical tests included Pearson χ^2 test for categorical data and the Wilcoxon nonparametric tests for continuous variables that were not normally distributed (such as LOS). A multivariate regression analysis was performed in order to predict mortality in both groups. The regression included adjusting to treating hospital in order to assess cluster effects by each facility. $p < 0.05$ was considered statistically significant. Randomized missing data were minimal.

RESULTS

During the study period, 1,261 patients were injured by terrorist explosions. Males were injured twice as much (69%)

TABLE 1. Demographic and Injury Data (VT vs. NVT Groups), % (n)

	VT (n = 109)	NVT (n = 1,152)	*p*
Gender			
Male	68.81 (75)	67.01 (772)	
Female	31.19 (34)	32.99 (380)	0.7
Age, y			
0–14	5.50 (6)	8.07 (93)	
15–29	55.96 (61)	49.91 (575)	
30–44	26.61 (29)	20.05 (231)	0.1
45–59	6.42 (7)	12.59 (145)	
≥60	5.50 (6)	8.33 (96)	
Unknown	0 (0)	1.04 (12)	
ISS			
1–8	10.09 (11)	54.25 (625)	
9–14	21.10 (23)	17.01 (196)	
16–24	17.43 (19)	10.50 (121)	<0.0001
≥25	51.38 (56)	15.54 (179)	
Unknown	0.0 (0)	2.69 (31)	

as females, and the majority of injured patients were young (15–29 years old).

Vascular trauma was diagnosed among 109 (8.6%) of the patients. The ISS was higher among VT patients, of whom 17.4% were severely injured (ISS, 16–24) as compared with only 10.5% among the NVT patients. Among the VT patients, 51.4% were critically injured patients (ISS, 25–75), as compared with only 15.5% of the NVT patients (Table 1).

Penetrating injuries were the most frequent type of trauma among explosion victims in both groups (51.6% in the NVT group, 64.2% in the VT patients) (Table 2).

Most (62.4%) of the VT patients were transferred to the trauma bay on their admission, as compared with only 29.9% of the NVT patients. Among the VT patients, 32.1% were considered to be in a state of hemorrhagic shock (systolic blood pressure <90 mm Hg) at admission.

Vascular trauma was mostly associated with a higher rate of multiregion injuries as compared with the NVT patients, except for skin and face injuries (skin, 31.16% in NVT vs. 12.84% in VT; face, 41.75% in the NVT group vs. 31.19% in the VT group) (Table 3).

Lower-extremity VT was the most prevalent (36.7%) injury followed by head and neck injuries (24.8%), upper extremity (18.4%), abdomen (15.6%), and thorax (13.8%) (Table 4).

Vascular trauma was a predicting factor for operative intervention. Most (91.7%) of the VT patients were operated on compared with only 48.3% of the NVT patients. Blood vessel repair was performed in 42.2% of the VT patients.

Intensive care unit admission rate among VT compared with the NVT patients was more than twofold (55.1% and 24.6%, respectively) (Table 5). Consequently, a significantly protracted LOS was observed in the VT patients group compared with the NVT patients group (median of 12 vs. 5 days, respectively, $p < 0.0001$). Furthermore, 40.4% of the VT patients were hospitalized for more than 15 days, compared with 17.7% of the NVT patients (Table 5).

TABLE 2. Mechanism of Injury (VT vs. NVT Groups), % (n)

Trauma Mechanism	VT (n = 109)	NVT (n = 1,152)	*p*
Blunt	11.01 (12)	30.56 (352)	<0.0001
Penetrating	64.22 (70)	51.56 (594)	0.01
Combined blunt and penetrating	24.77 (27)	16.49 (190)	0.03
Unknown	0.00 (0)	1.39 (16)	

TABLE 3. Body Regions of VT, % (n)

	VT (n = 109)	NVT (n = 1,152)	*p*
Head and neck	44.95 (44)	33.68 (388)	0.0181
Face	31.19 (34)	41.75 (481)	0.0320
Thorax	45.87 (50)	24.39 (281)	<0.0001
Abdomen	44.04 (48)	20.40 (235)	<0.0001
Upper extremity	44.04 (48)	31.94 (368)	0.0103
Lower extremity	50.46 (55)	36.98 (426)	0.0056
Skin	12.84 (14)	31.16 (359)	<0.0001

Patients might be injured in more than one vessel and more than one body region.

The mortality rate was significantly higher among VT compared with NVT patients (22.9% vs. 4.9%, respectively; $p < 0.0001$) (Table 5). The higher mortality rate among the VT patients was also demonstrated by multivariate regression analysis, after adjusting for age, sex, and facility (odds ratio, 2.9 [95.5% confidence interval, 1.51–5.72]).

DISCUSSION

The present study is the first description of the impact of VT caused by IED explosions, on the prognosis of civilian casualties. It is unique insofar as a single population and trauma care system were both exposed in a confined geographic area for a relatively short period, to such large numbers of casualties consequent to IED explosions.

Bombing and explosions directed against innocent civilians, in many diverse locations around the world, have become the primary tool of global terror to induce death, injury, fear, and chaos. The persistent terrorist attacks in Israel, the bombing of the Madrid trains, the suicide bombing attacks on the public transportation in London, the bombings in Iraq (during

TABLE 4. Distribution of Injured Blood Vessels According to Body Region, % (n)

Body Region	VT (n = 109	Injured Blood Vessels
Head and neck	24.77 (27)	Intracranial vessels, 15; carotid vessels, 8; other, 4
Thorax	13.76 (15)	Thoracic aorta, 4; innominate and subclavian vessels, 7; pulmonary artery, 3; other, 1
Abdomen and pelvis	15.60 (17)	Inferior vena cava, 7; celiac and mesenteric arteries, 3; portal and splenic veins, 3; other, 4
Upper extremity	18.35 (20)	Axillary vessels, 6; brachial vessels, 8; ulnar and radial vessels, 5; other, 1
Lower extremity	36.70 (40)	Femoral vessels, 20; popliteal vessels, 10; tibial vessels, 10

Patients might be injured in more than one vessel and more than one body region.

TABLE 5. Treatment and Outcome Data (VT vs. NVT Groups), % (n)

	VT (n = 109)	NVT (n = 1,152)	p
Trauma bay on admission	62.39 (68)	29.86 (344)	<0.0001
ICU admission	55.05 (60)	24.57 (283)	<0.0001
Operation	91.74 (100)	48.26 (556)	<0.0001
LOS,* median	12	5	<0.0001
LOS 15+ d	40.4 (44)	17.7 (204)	<0.0001
Mortality	22.94 (25)	4.86 (56)	<0.0001
Mortality predicted by multivariate regression†	Odds ratio, 2.9 (95% confidence interval, 1.51–5.72)		0.0015

*Missing values, n = 15 (1.19%).
†Adjusted for age, sex, ISS, and facility. Concordance index C = 0.93.

Operation Iraqi Freedom [OIF]), Afghanistan (during Operation Enduring Freedom [OEF]), Pakistan, Chechnya, and more have exposed the world to the devastating effects of suicide bombing attacks.[6,10–12,24]

Improvised explosive devices are easily and inexpensively manufactured and simple to activate and require no more than a determined perpetrator.[19] Many terror attacks were conducted by suicide bombers, wearing a vest loaded with explosive material and packed with multiple screws, nails, and other sharp objects, which intensify the injury and carnage. On-scene mortality rates from this kind of explosions are approximately 20% to 30%, while survivors suffer blast injuries (25%), shrapnel (20–45%), or burn injuries (15%).[1,3,6,8,10,11,13,22–33]

Projectiles, such as nails and metal balls embedded in the bombs, following the rules of ballistics, act as high- or low-velocity missiles, and their injury pattern reflects their size and shape. Different types of injury patterns have been defined for spherical missiles, nails, and screws, but the result of shrapnel damage or its injury pattern cannot be predicted. Multiple projectiles, causing penetrating injuries, combined with the tertiary blast injury, which throws the victim against solid objects, tend to cause larger tissue damage and injuries, with a higher degree of ISS, which are more complex to treat.[18–21]

Explosions cause either immediate death or severe injuries to subjects within close proximity of the explosion center and minor/moderate injuries to those further away from the same location. Because the kinetic energy of the shrapnel is maximal within the close range of the explosion center, it causes deep wounds and increases the probability of vascular injury.[27,28]

Previous reports by Peleg et al.[29] and Peleg and Jaffe[30] have shown that the patterns of civilian injuries in terror attacks are different from those of the military. The different primary setting—well-protected soldiers as compared with nonprotected civilians—renders the civilians much more vulnerable to terror attacks. Most of the civilian VT is secondary to penetrating injuries. Blunt VT, which is an uncommon occurrence, is caused by stretching, compression, and secondary thrombosis.[31]

The rate of wartime vascular injury has increased over time, from an average of 0.7% in World War I, to approximately 12% in Iraq during OIF and OEF.[23] White et al.[23] have demonstrated that explosions are more likely to lead to vascular injury than gunshot wounds. A report by Heldenberg et al.[15] described a 10% incidence of VT in terror-related settings, as a result of both IED explosions and gunshot wounds, compared with only 1% of VT among civilians in non–terror-related settings.[16]

Because an IED explosion activates a unique type of trauma mechanism involving multiple penetrating wounds as well as blunt force, the likelihood of blood vessel injury seems to be higher, compared with the more common trauma mechanisms.[24]

As expected, most of the casualties in the current study were secondary to penetrating injuries, causing high ISS. Similar reports, regarding the severity of injury as a result of terrorist bombing, have previously been described.[1,2,8,24,26–40]

Vascular injuries tend to cause either major bleeding and secondary hemorrhagic shock or tissue ischemia, both contributing to injury severity. Furthermore, major vascular injury, necessitating operative intervention, reflects major tissue injury, because most vascular components are deeply located. All the latter parameters may contribute to the higher ISS of the VT patients.

Indeed, our results indicate that VT was found as a major predicting factor of high ISS. The prevalence of severely injured patients (ISS, 16–24), among the VT patients was 1.7 times more as compared with NVT patients. Interestingly, the prevalence of critically injured patients (ISS, 25+) among VT patients was 3.3 times higher than the NVT group (51.4% and 15.5%, respectively). A large number of critically injured patients necessitates the full use of the admitting hospital's resources, such as ICU beds. Moreover, a high mortality rate is expected for these patients. In order to enable the admitting hospital to return to routine life as soon as possible, a secondary modulation of the VT casualties should be performed, especially if it was not completed during the primary modulation at the scene.

One might assume that the rate of vascular injuries among unprotected civilians would be much higher than the 12% described in the armed troops in OIF and OEF.[23] Nevertheless, in our study, vascular injuries were noted at a rate of only 8.6% in the unprotected civilians exposed to IED explosions. Our relatively lower rate of vascular injuries might be explained by the fact that many of the death-on-scene events were secondary to unsalvageable torso vascular injuries. These injuries were not reported by the national trauma registry, which takes into account only the details of the hospitalized patients. One might hypothesize that if those injuries were added to our data it would have increased the overall vascular injury rate.

The higher ISS of the VT patients reflects the destructive power of the IED. On the other hand, it points out that the very short evacuation time from the scene enabled the survival of patients with complex injuries and higher ISS who would have died on the scene had they not been evacuated quickly. Expeditious evacuation time was facilitated because of the fact that most terror attacks took place in the middle of cities with Level I trauma centers in proximity and that the Israeli emergency medical services are instructed to evacuate the casualties from the scene as soon as possible.

The same trend of increased incidence of extremity injuries described by White et al.[23] in OIF and OEF was seen in our study. The lower extremities were the most vulnerable body region in both cases. There is a major difference between these two studied groups—the injured soldiers survived because of their torso protection gear and arrived at the treating facility with mainly extremity injuries. On the other hand, most of the Israeli civilians who had severe torso injury probably died at the scene because of severe, unsalvageable vascular injuries. Those who were transferred to the hospitals could be subdivided into two major groups: those with mainly lower-extremity vascular injury, who did not have, in most of the cases, life-threatening injuries (these lower-extremity injuries, affecting mainly people who stood far from the explosion center, were generated due to shrapnel's flight according to the rules of ballistics[39]), and those patients with severe torso injuries who survived the scene owing to rapid evacuation.

This latter group consisting of severely injured VT casualties needed more trauma bay beds upon admission, more operative interventions, and more ICU beds. The mortality rate of these VT was five times higher than NVT patients. This outcome reflects the fact that in some cases, despite the short evacuation time that kept the patients alive for a while, they finally passed away in the hospital because of their basically unsalvageable injuries.

All these parameters and the fact that the treatment of VT patients tends to involve most of the hospital's emergency resources (such as operating rooms and ICU beds) should be taken into consideration during the process of patient evacuation from the explosion area. In such multicasualty incidents, patient evacuation, either in the primary setting or during secondary modulation, should be divided between several receiving hospitals in order to avoid an unnecessary burden on a small number of facilities.[41,42]

CONCLUSIONS

The current study presented the prognosis of civilian casualties of IED explosions. Vascular trauma casualties are more complex and have poorer prognosis. A very short evacuation time from the scene enabled the survival of patients with complex injuries and high ISS, who would have died at the scene were it not for their swift evacuation. The high ISS of the VT patients markedly increases the hospital's resource utilization. These facts should be taken into account either during primary evacuation from the scene or when secondary modulation is needed, in order reduce the burden of the admitting hospital.

STUDY LIMITATIONS

This retrospective study reflects the data gathered by the Israeli trauma registry. As was mentioned, no data regarding the cause of death at the scene were available. We assume that a higher rate of vascular injury would be found had these data been obtainable, because most of the deaths were secondary to unsalvageable torso vascular injuries. No data regarding long-term functional outcome are available.

DISCLOSURE

The authors declare no conflicts of interest.

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