Comparative Outcome of Bomb Explosion Injuries versus High-Powered Gunshot Injuries of the Upper Extremity in a Civilian Setting

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ABSTRACT: **Background:** Explosion injuries to the upper extremity have specific clinical characteristics that differ from injuries due to other mechanisms.

Objectives: To evaluate the upper extremity injury pattern of attacks on civilian targets, comparing bomb explosion injuries to gunshot injuries and their functional recovery using standard outcome measures.

Methods: Of 157 patients admitted to the hospital between 2000 and 2004, 72 (46%) sustained explosion injuries and 85 (54%) gunshot injuries. The trauma registry files were reviewed and the patients completed the DASH Questionnaire (Disabilities of Arm, Shoulder and Hand) and SF-12 (Short Form-12) after a minimum period of 1 year.

Results: Of the 157 patients, 72 (46%) had blast injuries and 85 (54%) had shooting injuries. The blast casualties had higher Injury Severity Scores (47% vs. 22% with a score of › 16, $P = 0.02$) and higher percent of patients treated in intensive care units (47% vs. 28%, $P = 0.02$). Although the Abbreviated Injury Scale score of the upper extremity injury was similar in the two groups, the blast casualties were found to have more bilateral and complex soft tissue injuries and were treated surgically more often. No difference was found in the SF-12 or DASH scores between the groups at follow up.

Conclusions: The casualties with upper extremity blast injuries were more severely injured and sustained more bilateral and complex soft tissue injuries to the upper extremity. However, the rating of the local injury to the isolated limb is similar, as was the subjective functional recovery.

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KEY WORDS: explosion injury, gunshot injury, civilian casualties, upper extremity injury, Injury Severity Score (ISS), Abbreviated Injury Scale (AIS)

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Bomb explosions (car or suicide bombs) result in multiple casualties and occur mainly in population centers. In comparison with gunshot victims, the injuries in explosion victims are allegedly complicated by the special nature of these bombs, combining both an explosion effect and shrapnel-causing penetrating trauma. There is little information in the literature shedding light on the epidemiology and outcome of civilian casualties injured in the upper extremity. Characterizing the patients and their injuries may aid in their treatment.

The objective of the present study was to compare the upper extremity injuries of bomb explosion and gunshot casualties in the civilian setting. The general injury status was examined as well as the upper limb injury and subsequent intervention. In order to asses the outcome of the patients we used the Disabilities of the Arm, Shoulder and Hand Measurement tool (DASH) to evaluate the functional recovery of the upper extremity [1,2] and the Short form-12 (SF-12) to evaluate the patients' well-being or general functional recovery [3].

PATIENTS AND METHODS

The trauma registry of our medical center, which prospectively collects the data on the patient's first admission to the hospital (including information related to the injury mechanism), was searched for any patient who had been injured in the upper extremity in attacks on civilian targets between October 2000 and February 2004 (ICD numbers 810.00-819.1, 828.0–828.1, 831.00–834.12, 840.0–842.19, 880.00–887.7, 903.00–903.9, 912.0–915.9, 922.33–923.9, 927.00–927.9, 943.03–943.59, 955.0–955.9). Appropriate consent was obtained from each patient, and the protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki.

During the study period 157 patients were admitted to the hospital after sustaining injuries in their upper extremities. Of these patients, 72 (46%) were injured in an explosion and 85 (54%) in shooting incidents. Patient characteristics are summarized in Table 1. The majority of gunshot casualties were male (88% gunshot vs. 43% explosion injuries, $P < 0.05$). We did not find significant differences between the groups in terms of age. These patients' files were retrospectively evaluated, focusing on the acute treatment during the first hospitalization after the injury and including evaluation methods, general injury severity and upper extremity injury characteristics, surgical treatment and discharge destination.

Table 1. Bomb explosion and gunshot upper extremity casualties in civilian settings

	Explosion	Gunshot	*P* value
Patients (n)	72	85	
Age, mean (SD)	27.3 (12.3)	27.0 (12.4)	NS
Gender (% male)	43.1	88.2	< 0.05
ISS > 16 (% of patients)	46.8	22.4	0.02
Length of hospital stay during first admission, days (SD)	14.4 (16.5)	9.8 (9.5)	< 0.05
Patients treated in ICU (%)	47%	28%	0.02
Upper extremity as main injury (%)	39	62.4	< 0.05
Bilateral upper extremity injury (% of patients)	36.1	16.4	0.02
Degree of upper extremity injury (% of patients with a maximal score)	30.6	36.5	NS
Operative treatment of upper extremity during first hospitalization (% of patients)	80.1	55.3	0.01
SF-12 PCS (SD)	33.6 (9)	32.7 (9)	NS
SF-12 MCS (SD)	53.8 (12)	48.5 (14)	NS
DASH score (SD)	26.8 (25.4)	25.6 (22.1)	NS

ISS = injury severity score, ICU = intensive care unit, AIS = Abbreviated Injury Scale, SF-12 = Short Form-12 questionnaires (PCS, MCS =physical and mental component summary scales), DASH = Disabilities of Arm, Shoulder and Hand questionnaire, NS = not statistically significant

The minimum follow-up period was one year (mean 34 months, range 12–80 months). The different parameters for the explosion casualties and gunshot casualties were compared. The variables examined were the injury severity in general (measured by the Injury Severity Score) and admission to an intensive care unit, the upper extremity injury (according to the Abbreviated Injury Scale score, and number of procedures), and the subjective outcome measures (DASH and SF-12 questionnaires) [4,5]. The SF-12 was subdivided into the physical and mental component summary scales (PCS and MCS).

STATISTICAL ANALYSIS

The chi-square, Fisher exact and two-tailed Student *t*-tests were used to evaluate differences among the two groups. The level of significance was set at $P < 0.05$.

RESULTS

INJURY SEVERITY

Patients in the explosion group were more severely injured than those in the gunshot group [Table 1] with more additional injuries to the upper extremity. An ISS score of > 16 was recorded in 46.8% of the patients in the explosion group vs. 22.4% in the gunshot group ($P = 0.02$). Forty-seven percent of explosion injury patients were admitted to an intensive care unit vs. 28% of the gunshot patients ($P = 0.02$).

There was a difference between the additional injuries between the groups. Head and neck injuries occurred in 33% of patients hurt in explosion versus 12% hurt by gunshot, chest injuries in 25% in explosion vs. 22% by gunshot, abdominal injuries in 13% in explosion vs. 11% by gunshot, and lower extremity in 39% hurt in explosion vs. 13% hurt by gunshot.

More explosion casualties died in the hospital due to their injury (four versus two gunshot casualties). The cause of death in these patients was not the upper extremity injury. In the gunshot group the upper extremity injury tended to be the most severe injury in 62.4% of the patients vs. 39% in the explosion casualties group ($P < 0.05$). Four of the gunshot casualties had shoulder injuries as part of their chest-penetrating injuries and were treated with chest tubes for evacuation of pneumohemothorax. Two patients in each group had injuries to the axillary artery as part of their shoulder injury. The patients with chest tubes or axillary artery injury were not among the patients who died.

UPPER EXTREMITY INJURY

The Abbreviated Injury Scale score of the upper extremity injury was similar between the two groups. Yet differences were found in several aspects. The explosion casualties had a higher rate of bilateral upper extremity injuries (36% vs. 16% in the gunshot group, $P = 0.02$). We found no significant difference between the two groups in the number of patients with neurological, vascular or soft tissue injuries, although more explosion casualties suffered from burns (43% vs. none of the gunshot casualties, $P < 0.05$). More open fractures were found in the gunshot group (55 vs. 25 in the explosion group, $P < 0.05$). No difference was found between the number of fractures treated operatively in the two groups (50% fixated in the explosion group vs. 45% in the gunshot group) [Table 2]. Nine patients had traumatic amputations, of whom five were explosion casualties and four gunshot casualties. The majority were finger amputations (three and four patients, respectively). Two explosion casualties had more proximal amputations, one at the forearm and one at the arm.

SURGICAL TREATMENT OF THE UPPER EXTREMITY

The surgical treatment is summarized in Table 3. In the acute period 89 procedures were performed in 72 explosion casualties (98 upper extremities) and 90 procedures in the 85 gunshot casualties (99 upper extremities). Further surgical treatment after the primary hospitalization was performed in 36 in the explosion vs. 22 in the gunshot group [Figure 1].

As mentioned, chest tubes were inserted in four gunshot casualties. Removal of foreign bodies was performed more frequently in the explosion group (20 vs. 6 procedures in the gunshot group), although in general, similar soft tissue procedures were performed in both groups. Seventeen fracture fixation procedures were performed in the 98 upper limbs of explosion

ISS = Injury Severity Score

Table 2. Location and type of injury in 98 upper extremities (72 bomb explosions) and 99 upper extremities (85 gunshot injuries)

		Amputation	Open fracture	Fracture	Soft tissue injury alone	Burn	Foreign body	Tendon injury	Total	Major artery injury	Nerve injury
Shoulder	Explosion	–	4	1	5	–	6	–	16	2	3
	Gunshot	–	17	–	3	–	9	–	29	2	6
Arm	Explosion	1	4	–	4	3	6	–	18	1	–
	Gunshot	–	10	–	8	–	5	–	23	2	4
Elbow	Explosion	–	2	1	7	1	1	–	12	–	6
	Gunshot	–	7	–	–	–	1	–	8	1	4
Forearm	Explosion	1	10	1	3	2	8	–	25	3	5
	Gunshot	–	4	–	8	–	6	–	18	2	5
Wrist	Explosion	–	–	1	–	1	4	2	8	1	2
	Gunshot	–	6	–	3	–	1	3	13	1	2
Hand	Explosion	3 (fingers)	5	1	8	17	2	3	39	–	–
	Gunshot	4 (fingers)	11	–	9	–	4	1	29	–	1
Not specified	Explosion	–	–	–	–	7	1	–	8	–	–
	Gunshot	–	–	–	–	–	–	–	–	–	–
Total	Explosion	5	25	5	27	31	28	5	126	7	16
	Gunshot	4	55	–	31	–	26	4	120	8	23

Table 3. Operative procedures performed on upper extremities of the 72 bomb explosion casualties (98 upper extremities) and 85 gunshot injuries (99 upper extremities)

Procedures performed during primary hospital admission			Further surgical treatment after primary admission		
Explosion	**Gunshot**		**Explosion**	**Gunshot**	
–	4	Chest tube placement	–	11	Wound debridement as primary intervention
2	6	Major artery repair	1	5	Removal of foreign bodies
6	9	External fixation of fractures	1	1	Skin graft
2	8	Closed reduction, internal fixation of fracture	1	1	Tissue flaps
9	8	Open reduction, internal fixation of fracture	–	1	Revision flap
18	16	Wound debridement	1	3	Hardware removal
20	6	Removal of foreign bodies	1	1	Manipulation under anesthesia
4	3	Revision of amputations	–	1	Distal interphalangeal joint fusion
10	6	Split-thickness skin graft	1	3	Open reduction, internal fixation with bone graft for fracture non-union
1	3	Fasciotomy (hand)	1	2	Forearm
1	2	Tissue flaps	–	1	Humerus
–	1	Revision external fixator to open reduction, internal fixation	1		Revision external fixation
–	1	Debridment of ex. fix. pin tract infection	–	2	Injection of growth factors to non-union site
3	4	External fixation removal or revision	3	1	Tenolysis (extensor tendons)
3	4	Tendon repair	4	4	Neurolysis
7	9	Nerve repair (including 2 sural nerve grafts)	2	2	Nerve graft (sural nerve graft)
1	–	Carpal tunnel release			
90	**89**	**Total procedures**	**22**	**36**	**Total procedures**

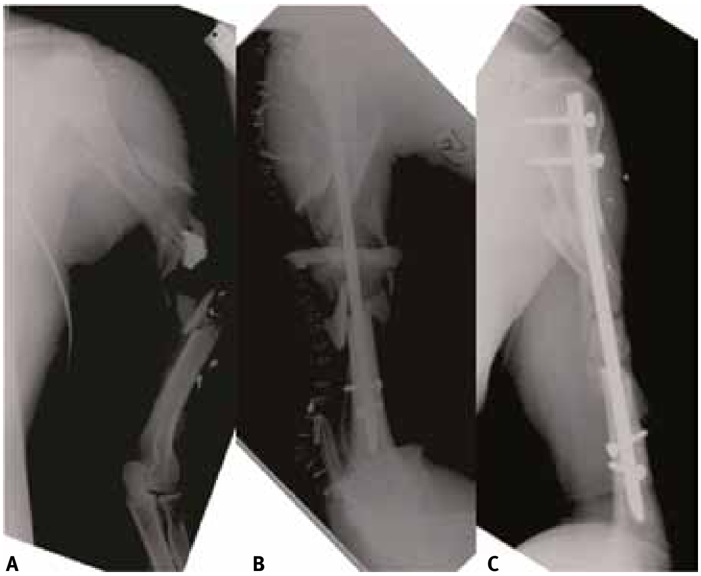

Figure 1. A 21 year old man injured in a bomb explosion in a restaurant, with 67 other casualties. He arrived at the hospital with 35 other casualties. He had a combined injury including a base of skull fracture, open rib fracture with pneumothorax and lung lacerations, and an open pelvic fracture. In addition, he had an open fracture of his humerus including full radial palsy and a closed proximal radial fracture **[A]**. He was treated with urgent debridement of his wounds and intramedullary nailing of his humerus **[B]** followed by primary repair of the radial nerve. Two years after the injury and after open reduction and internal fixation of the fracture with bone graft and the placement of demineralized bone matrix the patient still has non-union of his humeral fracture **[C]**, with partial recovery of his radial nerve function, although he does have good elbow range of motion as well as upper extremity function

casualties vs. 25 in the 99 limbs of the gunshot casualties. In all open fractures the soft tissue injury was treated surgically.

FOLLOW-UP

More explosion casualties were transferred to rehabilitation centers and not directly to their homes (21% of discharged explosion casualties vs. 10% of gunshot casualties discharged, although this was not statistically significant). The patients' final post-hospitalization destination could not be predicted by the severity or the type of upper extremity injury.

Forty percent of the gunshot group and 47% of the explosion group filled out the questionnaires (DASH and SF-12). Follow-up for more casualties was not possible due to several reasons: a) many could not be located; this may be due to the young study population as well as the temporary information collected by the hospital during the traumatic event itself, which was found to be outdated or incorrect at the time of the study; b) injured tourists and foreign workers usually could not be located for follow-up; and c) several patients refused to answer the questionnaires. We found no difference between the SF-12 or DASH scores between the casualty groups.

DISCUSSION

Our study demonstrated that the explosion injuries caused a more severe systemic condition in comparison with gunshot injuries. Explosion injuries involved more associated injuries, higher ISS and more admissions to the intensive care units. In contrast, we found no difference between the severity scores of upper extremity injury between the groups. We did observe that the upper extremity injury in explosion casualties included more bilateral injuries, more burns and more penetrating injuries of a different character than the gunshot injuries [Table 2]. In the gunshot group, there were more open fractures, and in general, the upper extremity injury tended to be the main injury in these patients.

The rate of amputation for explosion and gunshot casualties in this study of civilian injuries was similar and significantly lower than those reported in relation to high velocity missile wounds of war. In reports of war injuries, hand and forearm fasciotomies as well as amputations have been much more common (51% and 16% respectively) than in our explosion-injured patients from car or suicide bombs [6,7]. The rate of amputation of the upper extremity has been linked to the load of the explosion [6], which may be lower in the civilian scenario. The decreased rate of amputation in this study may also be due to the fact that in contrast to war, casualties are definitively treated in a hospital much earlier [8]. This would explain the fact that the rate of neurovascular injuries reported in war casualties [6] is similar to ours, but the amputation rate in our study was much lower. Higher rates of amputation and secondary amputations (after failed vascular repair) have also been reported with specific injuries [9] or injury mechanisms [10]. Low velocity gunshot civilian casualties were found to be related to low rates of amputation [11].

It is our experience that current standards of management of mangled upper extremities may not apply to all scenarios [12] and this should be evaluated for each case separately. In a combat scenario, Shin et al. [7] found that the addition of an upper extremity amputation in itself was correlated with an increase in injury severity. This was evident by increased ICU

DASH = Disabilities of the Arm, Shoulder and Hand Measurement tool
SF-12 = Short Form -12

ICU = intensive care unit

requirements, blood product utilization and hospital length of stay, although ISS was not found to be different when comparing the patients with upper extremity amputations to those without. The authors concluded that ISS underestimated the severity of these injuries in a combat setting. Recent reports stressed the limitations of the MESS (Mangled Extremity Severity Score) which has been reported as a guide in the evaluation of the mangled extremity [13]. In combat, shock and ischemia of the limb were found to be the most important factors in the decision to reconstruct or amputate a limb [13].

Relatively more procedures were performed in the explosion casualty group. This may be related to the combined injury mechanism – i.e., explosion fragments in addition to the primary blast effect [14]. Following the Balboa Blast Treatment Protocol, surgical treatment of the extremity begins with bony stabilization followed by soft tissue coverage and disability treatment. In our patient groups, bony stabilization was necessary more often in the shooting injuries, whereas soft tissue injuries were more prevalent in the blast injuries [Table 2]. It is known that the patterns of blast injuries are different in open vs. closed area explosions [15,16]. This may explain the variability in the injuries in different reports [16] and probably means that our study population is unique to the setting of bus explosions, the proximity of events to major trauma centers, and a medical staff that is familiar with the treatment of mass casualty events.

Despite these differences we could not demonstrate any difference in the general functional recovery of these patients, either mental or physical, using the SF-12 questionnaire. Regarding upper extremity function, we found no difference between the DASH scores in relation to the type of injury. Wide variations have been reported with DASH scores even for patients with specific conditions that are difficult to explain on the basis of variations in objective pathology alone [1,17]. Furthermore, the DASH has shown impairment with injuries other than the upper limb [18,19]. It is possible that more sensitive tools should be used to address the degree of disability in the limb, and that upper extremity injuries be divided anatomically or according to the pathology and not grouped together [20], especially in multi-trauma victims [21]. Even when the injury is isolated, a wide variability has been shown between the subjective report of dysfunction (the DASH score) and objective measures of impairment [22].

The trauma surgeon as well as upper extremity surgeons should recognize the differences between these injury mechanisms in order to optimize the treatment of these patients. While gunshot injury is commonly isolated, upper extremity explosion injury including blast fragments is usually part of a more severe multi-system injury. The multiple injury patterns involved in the explosion may require more surgical procedures according to the type of injury.

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