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Performance of the orthopedic surgical services of the General University Hospital Gregorio Marañón on the 11th of March terrorist outrage in Madrid

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ABSTRACT

Background: In recent years, we have witnessed dreadful terrorist attacks that increasingly affect us. Catastrophes imply physical damage and grievous bodily harm that can strain the capacity of available hospitals to provide quality healthcare. **Materials and Methods:** The authors describe and analyze the performance of the orthopedic surgery department at a university hospital faced with a terrorist attack that injured 1167 and killed 192 people.

Results: The injuries are characterized by severity and tissular damage spreading, including deep wounds, blast injuries, and burns.

Conclusions: The review of analyses of previous catastrophes, described by our colleagues in different studies, can be very useful inorder to avoid mistakes in the future.

Key words: Blast injury, catastrophes, mass casualty, terrorist attack

Introduction

Catastrophes can be defined as unexpected situations that cause property damage and physical injuries. The available resources are always insufficient, since these events involve numerous social bodies, such as: The forces of law and order, civil defense, and medical personnel. This necessarily leads to organization and coordination among these groups.

Bomb outrages and deaths by firearms are the most common means of terrorism. Explosions are chemical, physical, or nuclear processes that produce a significant and fast exothermic liberation of energy. The detonation is propagated at a supersonic speed within a radius of 5.000 m/s. From the center of the explosion emerges a shock wave that implies a change in atmospheric pressure, and produces a mass movement called explosion wind. At the epicenter of the explosion originates a front in which pressure instantly increases to a maximum, and then exponentially lowers to a sub-atmospheric level, to ultimately return to the environment pressure. This overpressure and thermal energy are the cause of the injuries by explosion [1-3].

In practice, these rules of pressure change depending on whether the explosion is outdoors or indoors. Primary injuries are related to proximity to the epicenter, and they are unusual in survivors but very common to people who die instantly. The vast majority of survivors have secondary and tertiary injuries, and these are treated similar to any other traumatic lesion. Primary injuries only affect the anatomical structures that contain gas. The solid organs are more resistant to the shock wave, and as a result, a patient with primary

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injuries may have no external sings of traumatism. This is better noticed in submerged patients, as the water spreads the waves and inhibits the movement of solid materials. Burns, a direct consequence of the heat from the explosive device or the fire of the explosion, are often observed and rarely, poisonings by dinitrobenzene [4] (Table 1).

These deleterious effects on human beings are called blast injuries. Depending on the explosive used, the utilization of shrapnel, the explosion environment, the closeness to the epicenter, and the height of the explosive compared to the victim, the injuries will be of different degrees and levels of seriousness.

The victims of these premeditated attacks show injuries that combine the lethal effects of deep traumatisms with the burns and the extensive physical injuries caused by the explosion.

Medical attention in a catastrophe, unlike in an ordinary emergency, reveals a disproportionality between the number of injured people, the seriousness of their lesions and the human and material resources available. That's the reason why, in these extreme situations, the

Table 1. Types of explosion lesions.	
Lesions	Mechanism
Primary	Gas structures
Secondary	Shrapnel
Tertiary	Body moving Physical damage
Quaternary	Burns Dinitrobenzene poisoning

Table 2. Stages for social-sanitary catastrophe control.	
Phase I	Activation
Actions	Communication Verification Leadership establishment
Phase II	Action
Actions	Rescue Triage Stabilization Transport Definitive treatment
Phase III	Recovery
Actions	Scene normalization Systems normalization Victim care Evaluation Reconstruction

use of resources in victims with very slim chances of survival, can take medical attention away from patients that could survive if cared for [5].

This plan of action must be applied to the highest number of victims, in the shortest possible time, in order to save the largest number of lives and reduce physical injuries.

With this scene of mass victims, the minimum acceptable care must be given to concentrate effort on the largest number of viable victims; this obviously is very far from the daily reality of health care whose aim is the best medical attention. The definitive therapy will begin when new victims stop arriving and we gain control of the situation [6] (Table 2).

Patient classification allows us to establish a priority order for the use of the resources [6]. Following the same priority criterion, we will guarantee priority access of the victims according to their injuries.

Materials and Methods

The performance and organization of the orthopedic surgery department at the "Gregorio Marañon" University Hospital, faced with a terrorist attack in Madrid (11, March) that caused 1167 injured and 192 deaths, is analyzed.

Terrorists detonated 10 explosives inside different suburban trains, at 8 O'clock in the morning, on a working day. Each explosive device contained 5 kg of a high explosive, together with a significant amount of shrapnel.

The hospital has 1600 beds and 22 operating theatres. At the time of the terrorist attack, 19 assistant doctors and 15 resident doctors were available in the orthopedic surgery department. The person in charge allocated tasks to the staff according to their experience; the most senior personnel positioned themselves at the point of victim arrival, in order to make a precise and quick classification, without taking part in the surgical procedures in the initial stage of triage and evaluation. They placed themselves at the entrance to the casualty department to meet the patients and to classify the seriousness of their injuries. These doctors went with the most critical victims to the resuscitation area, and they informed their colleagues in the surgical unit about the lesions found.

From the casualty department, depending on the

injuries, patients were sent to first aid, the resuscitation units or the available operating theatres. Multidisciplinary teams made up of an anesthesiologist, orthopedic surgeons, general surgeons, nurses, and nursing auxiliaries were created. Those medical teams, determined the need for a more exhaustive examination by sub specialized units of plastic surgeons, cardiovascular surgeons, thoracic surgeons, neurosurgeons, urologists, and otolaryngologists.

For the first 6 h, the triage surgeons, reappraised all patients searching for lesions that were not initially diagnosed. Other doctors put into effect a less medical, though essential, task: They discharged 161 patients admitted in the hospital (28 of them in the orthopedic surgery area) to ensure sufficient beds in the event of a possible overcrowding. Sixty-six scheduled operations were cancelled and 19 operating theaters were used.

From 8 O'clock in the morning to 1 O'clock in the afternoon, 331 patients were looked after, representing 25% of all victims of the terrorist attack. Of those 331 patients, 81 (24.5%) were admitted to hospital.



Figure 1. Wound to the skin covering the cranium in a young female patient.



Figure 2. Catastrophic inferior limb.

Table 3. Fractures sustained by our patients. Locomotor Open (Gustilo's Grade Closed Total apparatus fractures I-II-III) Femur 2 (0-1-1) 0 2 Tibia-fibula 7 (0-2-5) 8 1 Foot 2 (0-2-0) 0 2 Clavicle-scapula 0 2 2 Humerus 3 (2-0-1) 0 3 Ulna-radius 3 (2-1-0) 1 4 Hand 4 3 (1-0-2) 1 Vertebra 0 4 4

20

Total

9

29

We made an Excel[®] (Microsoft Corporation, Redmond, Washington, USA) table with personal details and injuries of the admitted patients and we analyzed it with the SPSS 9.0[®] software (IBM, Chicago, Illinois, USA). We noticed that 58% of the patients were men and 68% had Spanish nationality. 26% had burns, 22% tympanic perforations, 53% pulmonary contusions, 30% rib fractures, 5% acute abdomen, 20% craniocerebral traumatisms, 6% had loose scalps (Figure 1), 26% had facial injuries, 5% ocular lesions, 23% open fractures (Figure 2), 10% closed fractures, 5% vertebral fractures and just one patient had a spinal cord lesion (Table 3).

In order to classify the gravity of patients' injuries, the abbreviated injuries scale (AIS-85) and the injuries severity scale (ISS) were used, based on the intensity of the anatomical and organic injuries.

The ISS is the only anatomical scoring system that gives a good correlation with mortality, morbidity, hospital stay, and other parameters of severity. The AIS alludes to a given lesion's threat to life, but it does not constitute a measure of severity [7,8]. The average values, in the patients admitted, of the AIS-85 and ISS were 11 (3-28) and 20 (9-63), respectively.

An information center was set up in the teaching wing of the hospital, where psychologists, social workers, nurses, admission staff, and police identified the victims and gave this information to the relatives through all possible media, given that visitors were not allowed until the situation returned to normal. All scheduled activities were limited during the rest of that week.

Results

Thirty-one patients, one of them an expectant mother, were operated on by the 19 surgical teams until 1:00 p.m. They had 4 laparotomies, 4 craniotomies, 5 ocular reconstructions, 13 Friedrich's cures (Figure 3), 1 femoral supracondylar amputation, 1 fasciotomy of 1 leg, 3 external fixators were implanted (Figure 4), 1 femoral supracondylar traction (Figure 5), and 11 thorax vacuum tubes.

Two intraoperative exitus, 1 craneocerebral traumatism and one evisceration patient were reported and



Figure 3. Appearance after Friedrich's cure.



Figure 4. External fixator in open tibia fracture.

moved to a morgue temporarily set up in the rehabilitation gymnasium.

In the surgical action, antitetanic prophylaxis and empirical antibiotics were administered to patients according to their type of lesion and their immune report.

We tried to probe with a non-parametric test, such as the Fisher test, and found a correlation between the existence of lesions and sample variables, but we didn't notice any statistically significant association. The average ISS of the patients with fractures was 29, nine points higher than the total ISS of the patients admitted to hospital.

Discussion

Terrorist bombs usually have a few kilograms of explosives. In the air, the intensity of the initial shock wave decreases with the cubed distance from the epicenter, and that is the reason why primary lesions are less important than the secondary lesions caused by shrapnel, as this is what really produces the injuries from a distance. Primary injuries vary from 1% to 76% of the victims, although as a rule, secondary and tertiary lesions prevail. Mortality is in the 5%, range, unless the amount of explosive is very large and detonation occurs indoors causing collapse of the building.

After an attack, a lot of wounded people, brought by medical staff or witnesses of the tragedy, arrive at the casualty department in just a few minutes. Half of the people affected look for a medical service within an hour.

At the initial stage we focus our attention on signs of severe breathing difficulty and hemodynamic instability. Less than 50% of victims require hospital admission. In a bomb outrage, Einav et al. [8] and Almogy et al. [9] in two different papers reported that just 20%



Figure 5. Femoral supracondylar traction in a catastrophic inferior limb. Shown are the plentiful shrapnel.

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of the affected people needed urgent medical attention. The rest of the people who go to the casualty department are not emergency cases, and this creates difficulties for the examination of the seriously injured victims.

It's very difficult to evaluate the number of victims initially using the information given by the emergency medical staffs that take victims to the hospital. The number of affected people outdoors depends on the local population density, the number of bombs and the explosive charge; however, it's more predictable than when this kind of catastrophe happens indoors. Indoor explosions are associated with higher morbidity and mortality [10].

The death rate of the survivors with significant lesions increases in proportion to the mass of people when receiving the victims [11-13], and pulmonary trouble is normally the most lethal lesion among the early survivors [11,12].

The people who wear bulletproof vests are protected against the shrapnel but not against the shock wave, so they will show primary lesions of varying degrees of seriousness [11].

In most cases, the injuries are caused by the shrapnel propulsion (secondary lesions) and by the violent movement of the victims because of the explosion wind (tertiary lesions)[14].

The amputation of limbs is infrequent in the survivors of an explosion, being just 1.5%, however, it's rather common to those who die instantly, 19% [14]. The amputations happen when the persons in question are close to the explosion, but they are rare in the survivors. These amputations are localized at the level of the shaft of long bones, and not at the articulation level as was first thought. The lesions are caused by the interaction of the shock wave with the osseous tissue. These waves fracture the bone at the diaphysis level and the wind of the explosion will afterwards blow the fractured member off.

If the victims with limb amputations remain motionless, with no pulse and dilated pupils, they will be considered dead, so they won't be attended to and we will give priority to the evacuation of the remaining patients. The use of laboratory tests will be minimized or eliminated until no new victims are arriving at hospitals. Since we don't usually know the nature and extent of the terrorist attacks, we should always have a plan prepared, focused on moving patients that have already been treated to other hospitals, in order to have enough room for more possible victims [15,16]. The hospital examined used portable image intensifiers in the operating theaters, so as not to jam the x-ray unit and to obtain diagnosis quickly. The anesthesiologist's role as a resuscitator was vital to keep the patients who were operated on stable.

These patterns of lesions require detailed medical attention to patients, given that for example, the same victim may have, on the one hand, a burn and a fracture of a long bone that require a recovery of volume, and on the other hand, a pulmonary contusion that needs liquid restrictions [17].

The accordion approach is essential to reappraise the situation of these patients constantly, and to give their lesions medical care at the same time. This way, we can uncover hidden injuries that could endanger the life or the limbs of the victims that had initially been classified as not seriously ill.

Unlike other authors, we don't find a statistically significant connection between the existence of tympanic lesions and life-threatening injuries.

In spite of the high percentage of patients having a pulmonary contusion, we didn't detect the development of important respiratory distress.

Some determining factors were very important for a favorable medical outcome, such as efficient triage at the scene of the incident, the possibility of quickly moving the injured from the place of the terrorist attack due to the closeness to the hospital, and the low average age of the patients favoring the absence of a previous additional pathology.

We consider that the chronology of the explosions was essential for the correct medical attention given to the victims. It was thanks to the fact that the scheduled surgeries hadn't yet begun that we could establish a Level II of hospital treatment, and it wasn't necessary to go on to Level III, which implies moving patients to other hospitals, owing to a healthcare collapse (Table 4).

The horizontal work, carried out by multidisciplinary teams of experienced doctors, is vertically controlled from the resuscitation units and headed by very

Table 4. Hospital assistance standards.		
Level I	Usual assistance	
Level II	Programmed assistance cancellation	
Level III	Patient transfer to other hospitals owing to collapse	

qualified and clearly defined persons in charge.

It can give us very good results in circumstances where there is a disproportion between the number of victims, the seriousness of their injuries and the existing resources.

Our facts agree with studies of terrorist attacks in Ireland and Israel, where a higher rate of serious lesions than in unintentional traumatisms was described, because of the great impact of internal lesions (30%) [5,9,17]. The most affected parts of the body are the head and the extremities, and the most common internal lesion is the pulmonary one (54%), due to the majority of explosions happening indoors [9].

We haven't detected any difference with regards to the hospital death rate of the explosion victims in relation to gunshot victims, although persons wounded by firearms have a larger percentage of mortality in the first 24 h. For this reason, there is a longer average stay in the intensive care unit for the victims of an explosion [9], and these data are important in order to plan a proper medical management.

We could criticize the ISS since it only takes into consideration the three most altered parameters of the patient, and this system can underestimate the overall condition of the victim, given that these patients usually have more than three lesions, and besides, the ISS doesn't explicitly distinguish between open and closed fractures.

The critical analysis of former catastrophes can be very useful to avoid mistakes in the future. After the actions in the attack against the Murrah Federal Building in Oklahoma, it was recommended to avoid the additional triage load, and to give priority to the patients with moderate injuries to the detriment of those with severe lesions, as well as to restrict or eliminate imaging tests [17].

Considering that we are poorly prepared for giving medical attention to a large group of critical patients, it would be very helpful if we could have a predetermined and updated plan for a coordinated approach, based on the number of experienced doctors in every single hospital.

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Conflict of interest statement

The authors have no conflicts of interest to declare. **References**

- Greenberg MI, Jurgens SM, Gracely EJ. Emergency department preparedness for the evaluation and treatment of victims of biological or chemical terrorist attack. J Emerg Med 2002;22:273-8.
- Emile H, Hashmonai D. Victims of the Palestinian uprising (Intifada): A retrospective review of 220 cases. J Emerg Med 1998;16:389-94.
- 3. Roberts P. Patterns of injury in military operations. Curr Anaesth Crit Care 2003;13:243-8.
- 4. Horrocks C, Brett S. Blast injury. Curr Anaesth Crit Care 2000;11:113-9.
- Peleg K, Aharonson-Daniel L, Stein M, Michaelson M, Kluger Y, Simon D, et al. Gunshot and explosion injuries: Characteristics, outcomes, and implications for care of terror-related injuries in Israel. Ann Surg 2004;239:311-8.
- Katz E, Ofek B, Adler J, Abramowitz HB, Krausz MM. Primary blast injury after a bomb explosion in a civilian bus. Ann Surg 1989;209:484-8.
- Civil ID, Schwab CW. The abbreviated injury scale, 1985 revision: A condensed chart for clinical use. J Trauma 1988;28:87-90.
- Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: A method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.
- Einav S, Feigenberg Z, Weissman C, Zaichik D, Caspi G, Kotler D, et al. Evacuation priorities in mass casualty terror-related events: Implications for contingency planning. Ann Surg 2004;239:304-10.
- 10. Almogy G, Belzberg H, Mintz Y, Pikarsky AK, Zamir G, Rivkind AI. Suicide bombing attacks:

Update and modifications to the protocol. Ann Surg 2004;239:295-303.

- 11. Cohn SM. Pulmonary contusion: Review of the clinical entity. J Trauma 1997;42:973-9.
- Sorkine P, Szold O, Kluger Y, Halpern P, Weinbroum AA, Fleishon R, et al. Permissive hypercapnia ventilation in patients with severe pulmonary blast injury. J Trauma 1998;45:35-8.
- Pizov R, Oppenheim-Eden A, Matot I, Weiss YG, Eidelman LA, Rivkind AI, et al. Blast lung injury from an explosion on a civilian bus. Chest 1999;115:165-72.
- Mellor SG, Cooper GJ. Analysis of 828 servicemen killed or injured by explosion in Northern Ireland 1970-84: The Hostile Action Casualty System. Br J Surg 1989;76:1006-10.
- 15. Hull JB, Cooper GJ. Pattern and mechanism of traumatic amputation by explosive blast. J Trauma 1996;40:S198-205.
- 16. Zajtchuk JT, Phillips Y. Effects of blast overpressure on the ear. Ann Otol Rhinol Laryngol 1989;2:1-20.
- 17. Frykberg ER. Principles of mass casualty management following terrorist disasters. Ann Surg 2004;239:319-21.

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