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ORIGINAL ARTICLE

Pitfalls to avoid in the medical management of mass casualty incidents following terrorist bombings: the hospital perspective

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Abstract
Background The unique patterns of injury following explosions together with the involvement of numerous physicians, most of whom are not experienced in trauma, may create problems in the medical management of mass casualty incidents.
Methods Four hundred patient files admitted in 19 mass casualty events following bombing incidents were reviewed and possible areas which could impact survival were defined.
Results Forty-nine (9.3 %) patients had an Injury Severity Score ≥16. Of 205 patients in whom triage decisions were available, 5 of 25 severely injured patients were undertriaged by the triage officers at the door of the hospital. Following primary evaluation inside the emergency department critical injuries in two patients were missed due to distracting, less serious injuries. Of 68 (16.1 %) patients who were operated, 28 were in need of either immediate, urgent or high-priority operations. Except for neurosurgical cases which needed to be transferred to other hospitals, there was no delay in surgery. One patient underwent negative laparotomy. There were 15 in-hospital deaths, 6 of which were deemed as either anticipated or unanticipated mortality with possibility for improvement.
Conclusion Medical management should be evaluated following MCIs as this may illustrate possible problems which many need to be addressed in contingency planning.

Keywords Mass casualty incidents · Terror bombings

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Introduction

March 11, 2014 marked 10 years since the wave of terrorist bombing attacks in Madrid in which 191 died and over 1,800 were injured [1]. In the last two decades, we have experienced a surge in terrorist bombing attacks directed against civilians in the western world [2]. Many of these attacks were committed by suicide bombers.

Terror bombing attacks in the civilian setting commonly lead to an event with many casualties. In many past events, patients were transferred to several hospitals with the aim of distributing the casualty load between several hospitals. Nevertheless, it is not uncommon for many victims to be transferred to only a few selected hospitals [3–6]. It is also not uncommon for most of the critically injured patients to end up being transferred to the nearest hospital, whether this is a level I trauma center or not [7]. The overall impression from the literature is that hospitals have dealt well with these attacks, but it is important to remember that following terror bombings two fundamental problems arise in the hospital response. The first problem is that bomb

explosions create a spectrum of injuries which is different from that experienced every day by physicians who are accustomed to treating victims of penetrating and blunt trauma. The second problem is that the overwhelming number of victims transferred to hospitals following a mass casualty incident (MCI) demands a large number of medical staff to be involved in the treatment of the incoming casualties. Many of the staff are not trained in trauma. It could be that medical problems resulting from these two fundamental problems are underreported and problems in medical management should therefore be anticipated.

The purpose of this manuscript is to highlight the specific problems within civilian hospitals that arise in the hospital response and treatment of patients admitted following terrorist bombings reported in the literature and recorded in our mass casualty registry. With the waning of experience it is important to conserve lessons learned before the next round of MCIs following terrorist bombings takes place.

Methods

Between 1994 and 2005, 23 MCIs from bombing and shooting incidents were managed at the Hillel Yaffe Medical Center (HYMC) in Hadera, Israel. Of these, 19 were caused by terrorist bombings. Over 600 patients were transported to HYMC for primary evaluation and treatment. HYMC maintains an MCI registry in which clinical data of most of patients admitted was retrospectively recorded. For the purpose of this study we identified patients who were admitted following explosions. The following attributes were identified:

1. Severity of injury was defined by the Injury Severity Score (ISS), the New Injury Severity Score (NISS) and the Israeli Defense Forces' classification of severity of injury (IDF score) [8]. ISS and NISS were based upon AIS version AIS05 [9]. The IDF score defines the severity of injury within 24 h from admission:
   (a) Mild (delayed)—the injury is not endangering life and will not lead to permanent disability;
   (b) Moderate (urgent)—the injury is not endangering life immediately, but may do so if not appropriately handled, or, an injury leading to permanent disability.
   (c) Severe (immediate)—an injury endangering life.
2. Reliability of primary in-hospital triage was determined by comparing the triage officers' decisions on severity of injury with the patients' final ISS and IDF scores. The need to compare these decisions to the IDF score stems from our understanding that this score is defined in a similar manner to that of the triage decisions made by the triage officers.
3. Missed life-threatening injury rate was defined as the proportion of life-threatening injuries not recognized following primary triage and primary evaluation in the admitting area out of the total number of critical patients.
4. Operative needs were determined by identifying all those patients in need of operation. Types of operation and urgency of the surgical procedure were noted:
   (a) Immediate—unstable patient in need of immediate lifesaving operation;
   (b) Urgent—stable patient with life-threatening pathology, whose operation should be started as early as possible (<2 h);
   (c) High priority—stable patient with life-threatening pathology whose operation may be delayed, no more than 3–4 h;
   (d) Delayed—stable patients with injuries for which surgery can be delayed for several hours, such as limb-threatening injuries (4–12 h);
   (e) Non-urgent—stable patients whose surgery can be delayed beyond 12 h without untoward complications.
5. Negative laparotomies were identified and reasons for surgery analyzed.
6. Death analysis was done for patients who died in hospital according to the new criteria set by the American College of Surgeons [10, 11]. Probability of survival (Ps) was calculated using the Trauma and Injury Severity Score (TRISS) method, ISS, Revised Trauma Score (RTS) and age [12, 13]. Unanticipated mortality with opportunity for improvement (previously "preventable mortality") was considered if Ps was larger than 0.5 (Ps > 0.5) and ISS was lower than 20. Mortality without opportunity for improvement (previously "nonpreventable mortality") was considered if Ps was smaller than 0.25 or ISS was larger than 50. Victims with PS values between 0.25 and 0.5 and ISS between 20 and 50 were considered as anticipated mortality with possibility for improvement (previously "potentially preventable mortality").

Results

Four hundred twenty-two patients admitted in 19 mass casualty events following terrorist bombings were included in this study. Two hundred twenty-four (53.1 %) were male and 198 (46.9 %) were female. The mean age of patients admitted was 36.2 years (median 30, range 7 months–

89 years). Twenty-three (5.5 %) were children 12 years of age and under and 45 (15.4 %) were 66 years of age and older. Two hundred nineteen (51.9 %) were hospitalized for a mean of 7.7 days (median 2, range 1–136 days). Twenty-one (5 %) patients were hospitalized in the intensive care unit for a mean of 8.5 days (median 5, range 1–39 days). Injury severity of patients is recorded in Table 1.

Information regarding the in-hospital triage decisions were available for only 205 (48.6 %) of the patients. Table 2 presents the triage decisions in comparison to patients' injury severity as defined by ISS and IDF scales. Five and ten severely injured patients were undertriaged according to the ISS scale and IDF scale, respectively. Most of those undertriaged were triaged as mild rather than moderate.

Only two (7.4 %) of 27 life-threatening injuries were not identified following primary evaluation in the emergency department. Both these patients suffered from other distracting injuries. The first patient suffered from a transected pancreas coupled with severe upper extremity injury. This patient was hemodynamically stable upon arrival. She did complain of abdominal pain and epigastric tenderness was elicited during the initial examination. The surgical resident ordered a focused assessment with sonography for trauma (FAST). This revealed free peritoneal fluid. The ultrasound findings did not come to the attention of the trauma surgeons and she was admitted to the orthopedic ward for further evaluation and from this point forward, treatment of her extremity injury took priority. Tertiary survey of hospitalized patients missed this patient since she was in the operating room for her orthopedic injury at the time that other patients were evaluated in her department. Transection of the pancreas was only identified 24 h later on computed tomography (CT), which was ordered to evaluate continuous epigastric pain and tenderness coupled with high serum amylase levels. The patient underwent distal pancreatectomy. Recovery was complicated by a pancreatic leak and prolonged hospitalization.

The second patient presented with head and facial injuries together with a severe upper extremity injury and multiple penetrating injuries to the trunk. Significant bleeding from the extremity was controlled with a tourniquet. The patient was combative and extremely tachycardic. Following intubation he had CT where a minor epidural hematoma and facial fractures were diagnosed. A CT finding of free intra-abdominal fluid was disregarded. The patient was transferred to another hospital for neurosurgical evaluation. Tachycardia was assumed to be secondary to the profuse bleeding from the extremity which was now controlled. The patient arrived in shock to the second hospital where he underwent damage control laparotomy for active mesenteric bleeding and penetrating injuries to the bowel. Temporary shunt of the brachial artery conserved distal blood flow. Following resuscitation in the ICU he underwent definitive surgery. He eventually recovered.

Of 422 patients admitted in MCIs after terrorist bombings, 68 (16.1 %) underwent surgery for their injuries. One patient, who underwent negative laparotomy, is described

Table 1 Injury severity of 422 patients admitted following terrorist bombings

Scale				
ISS	Mild ISS 0–8	Moderate ISS 9–14	Severe ISS 16–24	Critical ISS ≥25
No. of patients (%)	361 (85.5)	22 (5.2)	13 (3.1)	26 (6.2)
NISS	NISS 0–8	NISS 9–14	NISS 16–25	NISS ≥25
No. of patients (%)	358 (84.8)	24 (5.7)	12 (2.8)	28 (6.6)
IDF scale	Mild	Moderate	Severe	In-extremis
No. of patients (%)	334 (79.1)	40 (9.5)	41 (9.7)	7 (1.7)

Table 2 Accuracy of triage officers' decisions in 205 patients

		Real severity of injury according to the ISS scale			
		Minor ISS 0–8	Moderate ISS 9–14	Severe ISS 16–24	Critical ISS ≥25
Triage officers' decisions	Mild	149	6	2	1
	Moderate	12	6	2	0
	Severe	3	4	5	15
		Real severity of injury according to the IDF scale			
		Mild	Moderate	Severe	In-extremis
Triage officers' decisions	Mild	144	8	6	0
	Moderate	9	7	4	0
	Severe	0	4	17	6

Table 3 Urgency and type of operation in 67 patients

	Neurosurgery	Trunk	Limbs	Ophthalmology	Other[a]
Immediate	1	9	3	0	0
Urgent	4	1	4	0	1
High priority	0	5	0	0	0
Delayed	1	0	23	3	1
Non-urgent	0	1	9	1	1

[a] Other operations—neck exploration (urgent); soft tissue injury (delayed); maxillofacial injury (non-urgent)

below. Table 3 presents the urgency and type of operation in sixty-seven other patients. The most common procedure deemed as either immediate, urgent or high priority was laparotomy while the most common procedure deemed as delayed was debridement and stabilization of open fractures.

One patient underwent negative laparotomy. She was a 65-year-old female patient who was intubated at the site of the explosion. On admission her GCS was 3, blood pressure was 60/36 and heart rate was 84. There were multiple penetrating injuries to the head, trunk and limbs. Her blood pressure gradually rose to 73/41. Chest X-ray revealed multiple metallic ball bearings in both hemithoraces, a left hemothorax and an endotracheal tube inserted too deeply into the right bronchus. Initial blood tests revealed a hemoglobin of 10.4 g %. Diagnostic peritoneal lavage (DPL) was negative for significant intra-abdominal bleeding. A CT of the head, neck, chest, abdomen and pelvis was performed. Head CT revealed an intracranial metallic fragment which had penetrated through the parietal bone and intraparenchymal hemorrhage throughout the tract of the fragment. Chest CT revealed left hemopneumothorax, multiple ball bearings in both hemithoraces. Abdominal and pelvic CT revealed free fluid in the abdomen without any clear signs of abdominal organ injury. Following CT, repeat CBC revealed a hemoglobin level of 7.2 g % and blood gasses revealed base excess of minus 7.1. Fearing the patient was actively bleeding in her abdomen and that the previously done DPL was misleading, a laparotomy was performed but no intra-abdominal bleeding or other injury was found. Following blood transfusions, her blood pressure gradually increased to normal levels. Following stabilization she was transferred to another hospital for neurosurgical evaluation and treatment. During her prolonged hospitalization in the tertiary facility she developed bowel obstruction and she underwent a second laparotomy.

Fifteen (3.5 %) patients died in hospital. Eight died within 24 h of admission and seven died later. Of the eight patients who died within 24 h of admission, six patients had lost their vital signs during transport at or near the entrance of the hospital. These patients did not respond to resuscitation and were declared dead soon after admission to the hospital. No postmortem examination was performed and the reason for these patients' death was not elucidated. Two other patients died during surgery after their admission. The first, an elderly male patient suffered from multiple significant penetrating thoraco-abdominal injuries. This patient died during prolonged surgery in which damage control principles were not fully observed. His death was assessed as being anticipated mortality with opportunity for improvement. The second, another elderly male patient died of acute myocardial infarction which probably developed secondary to major blood loss from soft tissue injury. This patient's death was assessed as being unanticipated mortality with opportunity for improvement.

Seven patients died between 5 days and 1 year following injury. Three patients died from sepsis and multiple organ failure which developed following emergency surgery. Death in two of these patients was deemed as anticipated mortality with opportunity for improvement.

Four other patients died as a consequence of penetrating head injuries. HYMC does not have neurosurgical capacity. Delay in treatment was possibly contributory to mortality in two of four neurosurgical patients. In total, of 15 patients who died in- hospital, death was deemed as either unanticipated or anticipated mortality with opportunity for improvement in six patients.

Discussion

Following terrorist bombings the proportion of patients suffering from critical injuries is commonly around 10 % or less [4, 5]. The main aim of treatment should be to make an impact on survival of these critically injured patients by allocating most, if not all, initial resources to the correct diagnosis and treatment of the severely injured victims. Those experienced in trauma management should be free of classical roles such as triage officer and incident manager. Instead, they should concentrate on the treatment of those severely injured since they are the most important resource that can make an impact on survival.

Most hospitals have a contingency plan which defines different areas of evaluation and treatment for critical and non-critical patients. Identification of critically injured patients commonly relies on decisions made by the triage officers. Data concerning reliability of these decisions in real events are lacking but can be discerned from different

reports published to date, which show that a proportion of critically injured patients were missed by this initial triage and were allocated to minor treatment areas (MTA) [14–16]. This finding is not surprising as triage is commonly done at an area exposed to many onlookers, limiting the possibility of exposure of the patients. The time available for making triage is measured in seconds.

Inadequate triage results in critically injured patients being sent to the MTA. Most commonly, the MTA is staffed by only a few physicians without experience in trauma. Complicating this situation is the observation that the MTA is commonly overwhelmed, with the majority of patients admitted to the MCI. The primary challenge of MTAs, as is true for other sites to which victims are allocated, is to quickly identify those patients who are critically injured and to transfer them to the responsibility of a trauma team equipped to provide these patients with optimal care as quickly as possible.

In our series, all but two life-threatening injuries were identified following primary survey within the treatment sites. Evaluation of all critically injured patients reveals that symptoms and signs are present to suggest the diagnosis of the life-threatening injury, making it feasible to identify these patients during primary evaluation even if initial triage was misleading. We assume from our limited experience that an important factor leading to missed injuries is the presence of distracting injuries and the fact that management of these patients was not directed by experienced trauma physicians.

In this series, 28 (6.6 %) of 422 patients reviewed were in need of either an immediate, urgent or high-priority operation for a life-threatening injury. MCIs, even if the number of victims admitted is limited, may be a challenge in small hospitals with a limited number of trauma physicians. Even in larger hospitals, occurrence of an MCI during non-office hours poses a challenge during the initial phases of the event. Triaging of operations according to their urgency may be of crucial importance in these scenarios. Again, no information is available in the literature to indicate that patients needing either immediate or urgent operations were not operated on in time due to lack of appropriate operating capabilities, either operating room or qualified staff. Nevertheless, this was observed during MCI practice drills in Israel (unpublished data).

Negative laparotomies in patients admitted following terrorist bombings were reported by other authors as well (Table 4). The first reason quoted for performing a negative laparotomy was liberal use of laparotomies in patients with false-positive abdominal ultrasounds. The second reason quoted was hemodynamic decompensation secondary to underestimation of external bleeding from soft tissue injuries and open fractures. Negative laparotomies are not without adverse outcomes as seen in the patient reported in this study. The observation that negative laparotomy is not a rare event demands review of these cases in detail. Until further data is available, our recommendation is for experienced trauma physicians to evaluate in detail patients in whom laparotomy is considered.

Death analysis is crucial following MCIs since making an impact upon survival should be seen as the major objective of the medical response. The fact that neither autopsy nor postmortem CT was done in patients who survived the initial event but were declared dead soon after being admitted to the hospital leaves us without answers to whether anything could have been done to save their lives. Probable causes of early deaths have not been made available to medical personnel by authorities in other countries as well. We should aim to formulate regulations which will require some form of evaluation concerning the cause of death in victims surviving to reach the hospital to be available to the medical teams responding to MCIs.

Seven patients suffered late deaths. Of these, four were assessed as anticipated deaths with opportunity for improvement. In two of these, a possible contributing factor was lack of immediate availability of neurosurgical capability in HYMC. Problems in management following transfer of these two patients to the tertiary facility with neurosurgical capability could not be assessed. Two other patients developed multiple organ failure following emergency surgery. Of concern is one elderly patient who was operated for an open fracture. Patients with open fractures following terror bombings commonly suffer from significant bleeding which is underappreciated. Elderly patients with open fractures should be treated according to principles of damage control surgery and are best resuscitated before committing them for operation.

Conclusion

The main aim of medical management in MCIs should be to make an impact on survival of those critically injured.

Table 4 Negative laparotomies reported in MCIs

References	Negative laparotomies (% of total laparotomies)	Probable cause
Madrid [1]	4 (24)	False-positive abdominal ultrasound
London [6, 17]	5 (100)	Hemodynamic instability
Oslo [18][a]	4 (50)	False-positive abdominal ultrasound
Current series	1 (6)	Hemodynamic instability

[a] Unclear whether bomb or shooting victims

Primary triage is inaccurate in identifying all these patients. Primary triage should be corroborated by repeat detailed examination since most, if not all, critically injured patients exhibit either symptoms or signs suggesting the real severity of their injury. In this series, critical injuries were missed due to the presence of other distracting injuries.

Prioritizing surgeries according to urgency is an important tool for managing surge capacity in hospitals with limited surgical capabilities. In this series, over 40 percent of operations were considered either immediate, urgent or high priority.

In-hospital death analysis may be a key to understanding problems in medical management. Postmortem CT or formal autopsy should be mandatory for those dead on or immediately after arrival if we wish to improve survival in the prehospital setting. Review of in-hospital deaths should concentrate principally on victims assessed as suffering from unanticipated mortality or anticipated mortality with possibility for improvement.

Ethical standards The study was approved by the Institutional Review Board at HYMC (0083-08). This article does not contain any studies with human or animal subjects performed by the any of the authors.

Conflict of interest Itamar Ashkenazi, Fernando Turegano, Sharon Einav, Boris Kessel, Ricardo Alfici, Oded Olsha declare that they have no conflict of interest.

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