Mass-Casualty, Terrorist Bombings: Implications for Emergency Department and Hospital Emergency Response (Part II)

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Abbreviations:
CISD = critical incident stress debriefing
CT = computerized tomography
ED = Emergency Department
EMS = Emergency Medical Services
HEICS = hospital emergency incident command system
ICU = intensive care unit
MCI = Mass-Casualty Incident
OR = operating room (theatre)
PPE = personal protective equipment

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Abstract
This article reviews the implications of mass-casualty, terrorist bombings for emergency department (ED) and hospital emergency responses. Several practical issues are considered, including the performance of a preliminary needs assessment, the mobilization of human and material resources, the use of personal protective equipment, the organization and performance of triage, the management of explosion-specific injuries, the organization of patient flow through the ED, and the efficient determination of patient disposition. As long as terrorists use explosions to achieve their goals, mass-casualty, terrorist bombings remain a required focus for hospital emergency planning and preparedness.

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Introduction

The first article (Part I) in this series demonstrated that the epidemiological outcomes, resource utilization, and time course of emergency needs in mass-casualty, terrorist bombings depend on a number of factors, including the type of attack, explosion setting, and explosion sequelae.[1] This article (Part II) builds upon these observations and considers their implications for emergency department (ED) and hospital emergency responses. A number of practical issues are explored here, including the performance of a preliminary needs assessment, the mobilization of human and material resources, the use of personal protective equipment (PPE), the organization and performance of triage, the management of explosion-specific injuries, the organization of patient flow through the ED, and the efficient determination of patient disposition. Although recent experience with terrorism suggests that it is prudent to "expect the unexpected", a rational approach to emergency management incorporates the lessons learned from previous experiences with terrorist bombings into the current basis for response.[2]

Implications for ED and Hospital Disaster Response

Preliminary Needs Assessment

Unless the entire hospital directly experiences a disaster, the ED usually is the first hospital area to learn that a mass-casualty incident or disaster has taken place in the community. Once an explosion occurs, a designated ED staff member should attempt to perform a preliminary needs assessment by obtaining key information from local emergency medical services (EMS) or police sources that might modify the ED response.

Identification of the bombing site is especially helpful, since the target identity supports the impression that a terrorist attack has occurred. Terrorist targets tend to be highly visible and

Bombing Characteristic	Implication	Anticipated Impact		
		Number of Injured Survivors Seeking Emergency Care*	Injury Frequency	Injury Severity
Blast site close to hospital	↑ number of injured survivors will arrive at ED outside EMS ↓ EMS transport time to hospital	↑ at nearby hospitals	↑ primary blast injuries, traumatic amputations, and many minor injuries	Variable – more minor and more serious injuries
Vehicle delivery system	↑ explosive magnitude Structural collapse possible ↑ immediate deaths close to detonation point or inside collapse	↑ May produce 100s to 1,000s of injured survivors	Variable	↑
Pre-explosion or pre-collapse evacuation	↑ distance between potential victims and detonation point ↓ number at risk	↓	↓ primary blast injury, traumatic amputations, flash burns	↓
Open-air setting	Blast energy dissipated, but spread over greater area Structural collapse unlikely ↓ number of immediate deaths	↑ May produce up to 200 injured survivors	↑ secondary blast injury	↓ – more injuries minor
Confined-space setting	Blast energy potentiated, but contained in lesser area ↑ number of immediate deaths inside space ↑ number of injured exposed to blast effects ↑ effects in smaller space (bus >> public room)	↓ Usually produces <100 injured survivors	↑ primary blast injury, amputations, burns	↑↑
Structural collapse result	↑ explosive magnitude Collateral damage outside structure possible ↑ number of immediate deaths inside collapse ↑ effects with taller building	Variable ↓ number from inside structural collapse ↑ number from outside structural collapse May produce 100s to 1000s of injured survivors	↑ inhalation injury, crush injury	↑
Structural fire result	↑ number of victims inside structure exposed to smoke and fire ↑ effects with taller building ↑ evacuation time in high rise fire	↑ number from inside structure	↑ burns, inhalation injury ↑ inhalation injury in high rise fire	Variable

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Table 1—Bombing characteristics and anticipated impact on hospitals (↑ = increased; ↓ = decreased; *Relative to population at risk)

play an important operational or symbolic role in the community, including government, military, commercial, and transportation assets. The target identity also suggests the number of potential victims at risk. For example, an explosion inside a crowded bus may place 60–80 persons at risk, while an explosion inside a multi-story building may put many thousands at risk, depending on other factors, such as the time of day, building occupancy, and surrounding crowd density. The location of the explosion establishes its proximity to the hospital and the potential for those injured survivors able to flee on foot to begin arriving at the ED within the next 5–30 minutes. The explosion location also determines the potential for incapacitated victims being distributed to other hospitals by EMS. Further information about whether a vehicle delivery system was used (e.g., car, truck, plane), explosion setting (open-air or confined-space), and explosion sequela (structural collapse or structural fire) helps establish a "quick and dirty" estimate of the initial need for

ED resources (Table 1). Since initial reports often are inaccurate or incomplete, it is important that a designated ED staff member remains in contact with prehospital sources and obtains updated information as it becomes available.

Resource Mobilization

The first priority of any ED faced with the aftermath of an explosion is to activate the hospital emergency or disaster plan in order to mobilize the capacity, (facilities, pharmaceuticals, and personnel) equipment, supplies, and personnel required by large numbers of victims. Concomitantly, a clear chain of command within the ED staff should be initiated by personnel well-trained in advance to work together under mass-casualty incident (MCI) conditions.

The Hospital Emergency Incident Command System (HEICS) provides a useful organizational tool for the command and coordination of hospital and ED emergency response.[3] The HEICS provides a predictable chain of command, clear lines of communication, prioritized actions, accountability of performance, and harmonized nomenclature.

Most EDs will have at least a few minutes from the time they are first notified of the event until the time the first victims arrive. During this brief period, the ED should be immediately cleared of as many patients as possible through discharge home or admission to the hospital. A pre-determined ED evacuation plan is critical, since the arrival of casualties into an ED still half-full with regular patients can lead to significant confusion. In Israel, regular ED patients are sent to pre-designated areas (usually internal medicine wards), where they are evaluated for possible disposition home by pre-designated teams of in-hospital physicians.

At the same time, hospital capacity also should be expanded rapidly. Hospitalized patients should be evaluated by pre-designated teams for possible disposition home. Elective surgery cases should be canceled and the recovery room should be cleared. Patients in intensive care units (ICUs) should be evaluated by pre-designated teams for possible transfer out. Besides their obvious uses, these critical care areas also may be needed to resuscitate victims in the rare instance when the number of critically injured exceeds the number of ED beds.

The total number of injured survivors that any single ED will receive varies with the characteristics of the bombing (Table 1). Maximum numbers of injured survivors seeking emergency care at EDs tend to occur when vehicles are used to deliver bombs and the hospital is close to the blast site.[1] In some communities, hospitals within a certain geographic area may be pre-designated to receive a certain number of casualties based on ED and hospital capacity. For example, all Israeli EDs are required to prepare for casualties numbering 15–20% of the total number of beds in their respective hospital.

While ED patients are being evacuated, the ED resuscitation area (as well as additional resuscitation-capable beds) should be prepared to receive the most critically injured victims. In particular, the equipment and medications for airway management and tube thoracostomy should be readied, since these are the two critical interventions most likely to be needed in bombing victims. In the setting of a small, confined-space explosion with rapid prehospital transport times, the need for these interventions increases, because relatively more survivors with pulmonary blast injuries will reach the ED.[4] In two bus bombings in Israel in 1996, 22 (42%) of 52 injured survivors were intubated and 10 (19%) received tube thoracostomies. In two open-air bombings in Israel that same year, only 13 (7%) of 190 victims underwent endotracheal intubation, and five (3%) received tube thoracostomies.[5] In the 1995 Oklahoma City bombing, with its resulting structural collapse, only seven (2%) of 388 injured survivors in 13 EDs underwent endotracheal intubation, one received a surgical airway, and three (1%) underwent tube thoracostomy.[6]

The need for blood transfusion can be dramatic in bombings that produce multiple victims with penetrating injuries.[7–9] In the 1991 London Victoria Station bombing, 113 units of blood were used in the first 90 minutes for 30 victims at Westminster hospital.[8] Nevertheless, pre-positioning of blood in the ED may lead to the wasteful use of blood by inexperienced and anxious physicians, resulting in blood being unavailable to the operating room (OR) or intensive care unit (ICU), where many casualties are sent within the first 30–60 minutes of an event. A pre-established supply line between the blood bank and the ED may obviate the need for pre-positioning. According to the Israeli ED protocol for mass-casualty incidents, a blood bank specialist is required to be physically present in the ED in order to maximize the efficient distribution of blood.

Simultaneously, a much larger minor treatment area separate from the main ED treatment area should be organized for the care of the first wave of survivors, most of whom will have minor injuries. An ED fast track area or hospital outpatient departments have been used for this purpose.[6,10] Since most patients will have soft tissue, orthopedic, ocular, and minor burn injuries, sufficient equipment, supplies, and medication (including analgesics, antibiotics, and tetanus immunizations) for the management of these clinical entities should be deployed.[6] The greatest reported number of injured survivors with soft tissue injuries seeking care at a single ED was 111 in the 1973 Old Bailey bombing in London, although Kenyatta Hospital probably received far more in the 1998 Nairobi bombing.[11,12] In the 1996 Oklahoma City bombing, 388 victims with soft tissue injuries were distributed to 13 EDs, and in the 1996 Manchester bombing, 129 went to five EDs, suggesting that EDs probably should prepare for at least 30–100 victims with soft tissue injuries.[13,14] Concomitantly, a third discharge area should be organized where discharged patients can await transportation home.[11] Suitable areas include the hospital lobby or auditorium. It is important to understand that resource mobilization is a dynamic process that evolves in response to ongoing needs as victims arrive over the first few hours.

Additional Personnel

At the same time that material resources are being mobilized, essential personnel also must be assembled. Injury patterns in those seeking emergency care in terrorist bombings

suggest that emergency physicians and trauma surgeons are the medical personnel most likely to be needed by large numbers of injured survivors, since they are trained in rapid assessment and general trauma care. Since virtually all mass-casualty, terrorist bombings produce a variety of serious injuries requiring specialty care, neurosurgeons, vascular surgeons, orthopedists, maxillofacial surgeons, and ophthalmologists also should be included in the initial response.[1,9,15] In addition, obstetricians should stand by for the assessment of pregnant casualties.

Anesthesiologists also will be needed for the many expected emergency operations and possibly to bolster ED resuscitation efforts, while radiologists and radiology technicians will be needed to expedite diagnostic imaging.[16] Adequate numbers of ED nurses and ancillary staff also should be organized.

Numerous reports exist of the logistical difficulties that arise when many well-meaning volunteers flood the ED in response to a terrorist bombing.[6,11,17] Strong consideration should be given to staging volunteers at a site separate from the ED triage and treatment areas. Access into the ED should be controlled by security and limited to specifically needed medical personnel.[6] Visible markers, such as baseball hats or colored vests, can be used to identify essential personnel.[16] Inexperienced volunteers require supervision by senior physicians. In the Old Bailey bombing, the only fatality was a patient with seemingly minor injuries who was treated by medical students, and then, had a cardiac arrest outside the ED.[11]

Personal Protective Equipment

All medical personnel involved in the direct care of victims require water-impermeable gowns, surgical masks, goggles, and gloves ("universal precautions") to protect against the transmission of blood-borne viral disease. At the same time that other supplies are being mobilized to anticipated patient care areas, personal protective equipment should be distributed unless already pre-deployed.

Triage

Another immediate priority is to setup a triage area at the entrance into the ED treatment area, which allows for unimpeded ambulance flow outside the ED and helps to avoid the immediate need to re-triage casualties once inside the ED. Triage can be performed capably by experienced emergency physicians or mid-level surgeons, saving senior trauma surgeons for more effective roles in the ED or OR.

The biphasic distribution of mortality in mass-casualty, terrorist bombings—a relatively high immediate mortality rate followed by low early and late mortality rates—suggests that the EDs rarely will be confronted with many simultaneously dying patients requiring a battlefield approach to triage ("greatest good for the greatest number").[1] Instead, the primary goal of triage is to identify surviving victims with immediately life-threatening injuries. The challenge of finding the relatively few critically injured bombing victims among the many with minor injuries is suggested by the in-hospital mortality rates of 19% for injured survivors with abdominal injuries and 15% with chest injuries in Beirut.[18] Respiratory distress, traumatic amputations, and flash burns are hallmarks of bomb proximity and provide immediate clues to the presence of other life-threatening injuries in survivors.[5] Pulse oximetry may be a useful triage adjunct.[19]

One common system for triage in this setting is the Simple Triage and Rapid Assessment (START) system, in which "immediate" victims are identified via their gross pulmonary, hemodynamic, and central nervous system dysfunction.[20] Although the many injured survivors arriving outside of the EMS in the early minutes usually are only minimally injured and are typically triaged to an alternative treatment area away from the ED treatment area, the very fact that casualties reach the ED on foot does not automatically place them in the not-seriously wounded category. Careful initial evaluation, frequent re-evaluation, and the organizational flexibility to re-triage injured survivors from one triage category to another are mandatory. Terrorist bombings are notorious for producing injured survivors with life and limb-threatening injuries that may not be apparent on initial evaluation. Injuries commonly associated with delayed recognition include pulmonary insufficiency due to pulmonary blast injury, intestinal perforation or solid organ injury due to abdominal blast injury, and delayed vascular injury due to penetrating shrapnel. Patient flow is facilitated further by the initiation of patient records at the time of triage using pre-numbered, pre-deployed, mass-casualty incident-specific charts, which are simply placed on the patient's gurney as it enters the ED.

Management of Specific Injuries

Explosions tend to produce victims with unique combinations of blast, penetrating, blunt, and burn injuries, requiring an integrated approach to their management. Although several articles have been published describing the management of explosion injuries, a few key points merit review.[20–25]

First, all injured survivors should be managed according to the general principles of advanced trauma life support.[26] Knowledge of the injuries associated with early death may help to optimize management in the ED. The rank order of injuries associated with early death is: (1) multiple trauma; (2) head trauma; (3) thoracic injury; and (4) abdominal injury. This order parallels injuries associated with immediate death.[9,13,19,27] Since head injury is a frequent cause of non-immediate death, special attention should be paid to victims with serious head injuries, who require cerebral resuscitation, prompt cranial computerized tomography (CT) scanning, and timely neurosurgical evaluation.[28,29]

Second, all injured survivors should be evaluated with a high index of suspicion for occult, primary, blast injury. Patients at particular risk for occult pulmonary or abdominal blast injury include survivors of small, confined-space explosions and survivors close to the detonation point (e.g., with traumatic amputations or significant flash burns).[1,4,5,30] Such patients require chest radiography to look for signs of pulmonary blast injury, including contusion (often in a "butterfly" or bihilar pattern), pneumothorax, pneumomediastinum, subcutaneous emphysema, or bilateral "white-out" suggestive of blast lung syndrome.[31,33] Positive pressure

ventilation is challenging in patients with pulmonary blast injury, since high peak inspiratory pressures increase the risk of iatrogenic air embolism or pneumothorax.[21,23,24,33–35] Preventative strategies include using limited peak inspiratory pressures, pressure-controlled ventilation, high frequency jet ventilation, and permissive hypercapnia.[24,30,33,35] Intravenous fluids should be administered judiciously, since fluid accumulates in damaged pulmonary tissue.[32,33] There is no routine role for corticosteroids or antibiotics in uncomplicated pulmonary blast injuries.[20] The empiric insertion of bilateral needle thoracostomies in rapidly deteriorating injured survivors has been advocated in case of occult pneumothorax.[30]

Injured survivors also require careful evaluation for abdominal blast injury, which notoriously is difficult to detect initially.[36] Fatal splenic rupture has been reported in at least one victim with no sign of external injury, whose only initial complaint was abdominal pain, suggesting a role for FAST ultrasonography in symptomatic or for patients who cannot be evaluated.[7] Although tympanic membrane rupture no longer is considered to be a marker for pulmonary blast injury, all injured survivors require otoscopic examination.[37] Hearing loss, which may occur without any sign of physical injury, creates a considerable challenge for communication in disaster situations.[26,38]

Finally, soft tissue injuries should be managed with the goals of detecting underlying injury and preventing infection. Because terrorist bombings generate shrapnel of various sizes and forms, even innocuous-appearing wounds may portend life-threatening penetrating thoracic, abdominal, or vascular injury.[36,39,40] In particular, penetrating limb injuries should prompt careful and sequential evaluation of vascular integrity, since delayed vascular occlusion may occur. For example, two victims of the Tel Aviv Dolphinarium bombing required reconstructive vascular intervention hours after normal pulses were initially noted.

Wounds should be irrigated thoroughly on initial examination, and subsequently debrided, dead tissue excised, and as many fragments as possible removed without causing further damage. Soft tissue loss and contamination may be so extensive that excision and debridement is best performed in the OR. Most secondary blast wounds should be left open for delayed primary closure, particularly those involving muscle or in the buttock or thigh areas.[39,41] Foreign bodies not easily identified can be removed at a later date.[11] Injured survivors also require a careful eye examination, since penetrating ocular trauma due to flying fragments is relatively common.[42,43]

Patient Flow

An ED command and control post is mandatory. This post should have an overall perspective of the patient load capabilities of units receiving patients from the ED, such as computerized tomography (CT), angiography, operating rooms (ORs), intensive care unit (ICU), and holding areas. This overview should help to avoid overloading specific sites or keeping seriously ill patients in areas at risk for suboptimal care, such as corridors. This command and control post also fields requests for assistance from the ED and other hospital units (e.g., porters or orderlies, medications, etc.), directs emergency personnel according to changing patterns of bed occupancy, gathers data for hospital, regional, or national official use, and assists the hospital emergency incident command administrative officers with media communications strategy. The subdivision of the ED into large care areas with clear chains of command and lines of communication is particularly helpful. Ideally, this organizational scheme will have been addressed a priori in the ED and hospital disaster plan.

If manpower is sufficient, then the one-to-one assignment of physicians to victims may expedite care.[11,44] The assignment of specific tasks also may be helpful. For example, in the 1987 Enniskellen bombing, one physician was assigned to ensuring that all ED patients had adequate pain control.[10] The use of non-physicians or junior medical personnel as scribes may free physicians to provide medical care and may improve documentation, but also may exacerbate the problem of overcrowding.[19] Senior physicians tend to benefit more patients when they assume a supervisory role.[11]

Radiography is the most common bottleneck in the ED flow of many simultaneously injured bombing victims.[45–47] In the 1995 Oklahoma City bombing, 45% of 265 ED patients received at least one plain radiographic study, while in the 1996 Manchester, 50% of 208 victims received at least one radiographic study.[6,14] In the 1980 Bologna bombing, 43% of 107 hospitalized victims underwent an average of 2.2 radiographic studies.[48] Solutions to this bottleneck include bringing portable radiography machines into the ED from other hospital areas or diverting patients with minor injuries to alternative areas in the hospital, such as another location where a portable radiography unit has been set up.[19] Portable chest x-rays are a priority for victims suspected of having pulmonary blast injury.[10] Since many radiographs can be safely deferred (e.g., for foreign bodies and fractures), all other radiographs should be prioritized according to their likelihood of changing immediate management (minimal acceptable care) and should be specifically authorized by a supervising senior physician.[11] It is important to appreciate that the zealous use of portable radiography in the busy ED may disrupt patient care because of the need to evacuate the vicinity of the radiography machine. On the other hand, patients sent out of the ED for radiographs should be selected carefully, due to the danger of removing them from the well-organized management system within the ED. Finally, it may be helpful to assign one or more radiology technicians to the dedicated task of processing all plain films, freeing other technicians to actually take the radiographs.

The CT scanner is a significant bottleneck in the ED flow of critically injured victims.[47,48] In Oklahoma City, 19% of ED patients underwent CT scanning of all types, suggesting the need to prioritize this resource based on the urgency of finding a surgically remediable problem.[6] The CT scanning area is another place where waiting patients can deteriorate unnoticed, suggesting the need for monitors, resuscitation equipment, and prepared staff in adequate numbers. The presence of an attending radiologist to immediately read radiographs and CT scans may expedite flow through these areas.

Other than blood typing, routine laboratory tests only rarely are helpful during the ED phase and should be avoided. A portable blood gas machine brought into the ED may expedite the evaluation of large numbers of victims with inhalation injury.[19]

Disposition

While individual patient care decisions are made at the bedside, disposition decisions should be made by a designated senior trauma surgeon in order to ensure prioritization and coordination with receiving areas, such as the OR or ICU, and to minimize the possibility of overtriage.

Stein[30] recommends the following priority for OR disposition: (1) hemodynamically unstable patients requiring hemorrhage control; (2) hemodynamically stable patients with life-threatening torso injuries (solid organ injury, hollow viscus rupture); (3) closed head injuries with expanding hemorrhage without extensive brain damage; (4) vascular and orthopedic injuries; and (5) wounds requiring debridement and cleansing. When OR resources are insufficient, strong consideration should be given to transferring stable patients requiring lengthy procedures (skeletal stabilization, wound debridement, ophthalmologic procedures, plastic surgery, nerve reconstruction) to other hospitals (secondary distribution).[30] Burn victims also frequently are transferred when specialty resources are not available at a particular institution.

Patients exposed to high blast overpressure require close observation for blast lung syndrome, which may evolve over the first 12–48 hours and subacute intestinal perforation, which may not become apparent clinically for two or more days.[4,7,28,48–50] The longest reported delay in diagnosis of subacute intestinal perforation is seven days.[4]

Patients with auditory blast injury require referral to an otolaryngologist. Those with tympanic membrane rupture should be re-examined in 24 hours, at which time any debris can be removed under microscopic suction. Since 50–83% of ruptured tympanic membranes heal spontaneously, tympanoplasty is reserved for perforations that fail a conservative approach.[22,27] Those with isolated hearing loss also should be reassured that symptoms usually resolve without further care.[38]

Referral for critical incident stress debriefing (CISD) also should be considered. In the 1996 Thiepval Barracks bombing in Northern Ireland, 407 people underwent CISD between 66 and 96 hours after the attack.[51] Although the benefit of CISD in decreasing long-term psychological sequelae in victims of trauma is questionable, it may help those involved "normalize" the event.[20,52–55]

Conclusion

Bombings are the most likely disasters associated with terrorism. Following a mass-casualty, terrorist bombing, a large number of immediately surviving injured will begin seeking emergency care in a very short time. Key components of early ED and hospital emergency response to these incidents include the performance of a "quick and dirty" needs assessment based on the characteristics of terrorist bombings, activation of the hospital disaster plan, mobilization of material and human resources, use of appropriate personal protective equipment (universal precautions), establishment of a triage site immediately outside of the ED, and performance of triage in such a way as to identify those victims with life-threatening injuries first. Other critical components of ED and hospital response include the appropriate management of explosion-specific injuries, prioritized allocation of resources to improve ED patient flow, and efficient determination of patient disposition. As long as terrorists use explosions to achieve their goals, terrorist bombings must remain a focus of hospital emergency planning and preparedness.

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