Mass-Casualty Victim "Surge" Management

Preparing for Bombings and Blast-Related Injuries with Possibility of Hazardous Materials Exposure

Harry W. Severance, MD, FACEP

THE DAILY NEWS MAKES IT ALL too clear that bombing of civilian structures, both here and abroad, is a real and ongoing threat.[1] In the United States alone between 1980 and 1990, there were 12,216 intentional bombings.[2] North Carolina itself is not immune from such events. Table 1 lists some of the major intentional bombing incidents that took place in, or in proximity to, North Carolina. Approximately 200 bombings were reported in this state from 1996 to September 1998 (Figure 1).

Injuries can result from accidental explosions in factories or fuel depots, or from intentional bombings such as those related to terrorism. Large blasts often produce such massive numbers of victims that medical systems can be totally overloaded and incapacitated unless they are prepared to handle the medical consequences of such events.[1,3]

Bombs are attractive to terrorists because, compared to other weapons of mass destruction, they are relatively easy to design, assemble, and deliver, and because they are sudden and violent in nature. Large explosions attract media coverage and produce large numbers of casualties—both of which further the terrorist goal of disrupting society. A common tactic is to set off two or more devices over time because, once media and initial responder attention is focused on the first event, the subsequent devices produce further casualties, further disruption, and more media attention.[1]

Recent information suggests that terrorists are working on explosive devices purposefully contaminated with radioactive, biological, or chemical agents (see Table 2 for a partial list[4]), to be detonated *after* an initial explosion has drawn multiple responding agencies to the scene. At least one recent terrorist bombing (the initial World Trade Center bombing in 1993) is reported to have unsuccessfully attempted the release of cyanide at the blast site.[5]

The introduction of victims contaminated—intentionally or accidentally—with hazardous materials into care systems unprepared for such conditions inevitably leads to contamination of pre-hospital and in-hospital care providers, other patients, visitors, and families. The potential morbidity and mortality that follows such contamination is at least theoretically avoidable by having in place special preparations, protocols, and paradigms to deal with possible blast events producing mass casualties, exposure to hazardous materials, or both.

Pathophysiology of Blast Injuries

Explosions produce injuries through primary, secondary, tertiary, and quaternary (or miscellaneous) mechanisms.[1,6,7] Primary injuries are those that are produced by the initial blast wave emanating concentrically from the center of an explosion.[1,6-9] The high pressure wave front (incident pressure) from an explosion is measured in kilopascals (kPa), or pounds per square inch (PSI). When the wave strikes a solid object, it produces a reflected wave front that has a pressure two to nine times higher than the original incident pressure.[7] This means that victims of blasts occurring in enclosed spaces like buildings or vehicles, and victims located between a blast and a solid structure, suffer much worse injuries than would be predicted from the peak blast pressure and the victims' distance from the blast center.[7]

Most primary blast wave injuries occur when tissue

Dr. Severance is Associate Clinical Professor and Attending Physician in the Division of Emergency Medicine, Department of Surgery, and Asisstant Professor in the Department of Medicine, at Duke University Medical Center. He is a founding member of the former Governor's Counter-Terrorism Task Force, and he advises various state, federal, and military agencies on multi-blast casualty management. Address correspondence to him at *Box 3096,* DUMC, Durham, *NC 27710.* Telephone: *919/684-5537.* Email: harry.severance@.duke.edu.

interfaces with fluid or gas, or at tissue boundary-tethering points. The zone in which pressure exceeds the injury threshold (15 PSI) extends concentrically from the center of the blast, and injuries occurring within that zone are much more likely to be lethal. A pearl of clinical wisdom is that rupture of the tympanic membranes means the victim has been exposed to potentially deadly pressures exceeding 15 PSI.[1] Most on-scene deaths result from primary blast injuries.[1]

Secondary blast injuries are caused by the wind that immediately follows the blast wave.[1,7-9] The displacement of air caused by the explosion accelerates debris, causing penetrating injuries similar to bullet or shotgun wounds. Most of the victims who survive a blast event will be in this group.

Tertiary blast injuries are those caused by acceleration/deceleration of bodies subjected to blast forces.[1,7,8] Powerful explosions exert enough force to hurl large objects (including human bodies) that are located close to the blast. When acceleration/deceleration forces are directed at specific body parts (for example, a bomb under a car seat) or when a part of a body (usually an extremity) strikes a resisting structure, the body part is amputated. Victims who have suffered a blast amputation are highly likely to have been exposed to lethal blast forces.

The term quaternary refers to all other blast-related injuries.[1,7] This category includes burns from the heat of explosion, crush injuries from collapsing walls, contamination from nuclear radiation or from the biological and chemical agents found with terrorist-related "dirty" bombs or industrial explosions.[1] The vast majority of blast t ms n seco d- ou th-degree injuries survive; most of those who suffer first- or third-degree injuries die in the blast or shortly thereafter.[9,10]

Table 1. Selected terrorist bombing attacks on the East Coast of the US, 1993-2001

New York, NY: World Trade Center, September 2001
Washington, DC: Pentagon, September 2001
Fayetteville, NC: Double clinic bombing, October 1998
Birmingham, AL: Clinic bombing, January 1998
Atlanta, GA: Clinic bombing, January 1997
Atlanta, GA: Olympic Park Bombing, July 1996
Raleigh NC: BTI bombing, July 1995
New York: World Trade Center, February 1993

Source: Needham D. NC Emerg Mgt

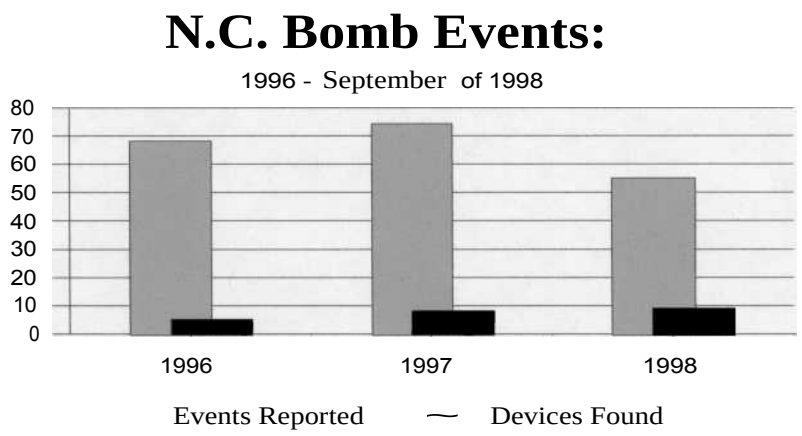

Figure 1. Bombing incidents reported in North Carolina, 1996 to September 1998.

Table 2. Biological agents with weapons potential (partial list)

Bacteria	*Toxins*	*Viruses*
Anthrax	Botulinum	Smallpox
Brucellosis	Staphylococcal Enterotoxin B	Viral Encephalitis
Plague	Ricin	Viral Hemorrhagic Fevers
Q Fever	T-2 Mycotoxins	
Tularemia	Clostridium perfringens toxin	Hantavirus
Cholera	Aflatoxins	Equine morbillivirus
Typhus	Shigatoxin	

Modified from: Miller K., Fire Engineering 1999;152:83-9.

Medical Management of Bomb-Blast Scenes

The medical and surgical treatment of the traumatic injuries suffered by victims of blasts is well described elsewhere.[11-13] When victims are relatively few in number, management follows established pre-hospital and in-hospital plans for multi-casualty events. What are not well described are tactics for managing situations in which the number of casualties exceeds the ability of a local system to respond—a mass-casualty situation.[1,3,9] Explosions from intentional bombings and other blasts are among the few instantaneous traumatic events that can produce massive numbers of casualties requiring immediate medical attention.

The possible presence of hazardous materials in terror

Table 3. Triage figures from the Murrah Federal Building, Oklahoma City, 1995

Deaths	169 (including 19 **children)**
Nonfatal injuries	601
Treated at area hospitals	426
Released	344
Admitted	82
Treated in area doctor's offices	175

ist-related blast events and certain industrial accidents make the problem of multiple severe injuries even more dangerous. Biohazards may not be detected or recognized at first, so all blast-related events suspected or known to be intentional should be handled as though they involved biohazardous agents. Failure to take such precautions means that unprotected first responders, emergency department personnel, and everyone exposed during or after the introduction of contaminated victims into the emergency department or hospital could become sick or even die.

Since the mid 1990s, there has been a recognized need for timely coordination and interaction of pre-hospital personnel who respond to and perform various duties at mass-casualty scenes. In response to this need, federal legislation has fostered development of national, regional, and local "incident command" systems. The "incident command" system provides unified central command and control of all agencies that respond to such events; its goal is to insure that each agency performs its duties in a timely fashion without impeding the critical functions of other medical and non-medical agencies. Local level incident commands include local law enforcement agencies, Emergency Medical Services, Emergency Management, Fire-Rescue and others.[1]

In 1995, Presidential Decision Directive 39, which assigned lead incident command responsibility in cases of domestic terrorism to the FBI, defined responsibilities of and coordination among federal agencies.[14] As in the case of natural disasters, the Federal Emergency Management Agency (FEMA) coordinates federal assistance to state and local governments; other federal agencies like the Departments of Defense, Energy, Transportation, Agriculture, Health and Human Services, and the Environmental Protection Agency can be called upon to assist the FBI and FEMA as necessary.[14] SARA Title III (Community right to Know Act) requires federal, state, and local governments to plan for chemical emergencies, especially mass casualty events.[15] When a mass-casualty event like a bombing occurs, the local incident command system is activated, and regional or national units respond as conditions dictate and time allows.

One major shortcoming of current response scenarios concerns the delivery of immediate medical care to victims of mass-casualty blasts. Almost no community has plans to manage the massive surge of patients that occurs in the first few hours after such an event. In most communities, standard protocols call for transporting injured victims to nearby hospitals. This is a special concern when survivors may be contaminated with biologically hazardous agents.

The great majority (85-90%) of injuries suffered by immediate survivors of bombings and other blasts are not imminently life-threatening, and most victims are able to walk. This means a relatively small proportion of victims (5-15%) need immediate and intensive trauma care and stabilization (see Table 3). Still, if the injured number in the hundreds or thousands, a "relatively" small percentage can overwhelm the resources of emergency and hospital systems.[1] Most hospitals in this country are not currently prepared to deal with large numbers of simultaneously injured victims who might be contaminated by hazardous materials. It is not likely that any North Carolina Trauma Center could maintain hazardous materials precautions while providing decontamination, primary intervention, and definitive surgical intervention services to more than 1-4 cases/hour.

Of even greater concern is the management of the much larger number of less severely injured victims. The 80%-95% of victims of blast and other mass casualty events who constitute the "walking wounded" will, if they perceive that their injuries are not being rapidly addressed on-scene, begin showing up in large numbers at nearby emergency departments and clinics.[15] The sheer number of casualties might well overwhelm emergency departments and clinic providers, and thereby hinder the care of critically injured victims. Another problem is that clinics and hospitals are not prepared to block access by victims potentially contaminated with biohazardous materials. In fact, it may be easy to recognize that a bombing was intentional, but it may take days to identify the presence of biohazards. By then ambulatory victims will have sought care in (and contaminated) local facilities. The key question is this: Can we provide adequate and rapid care for ambulatory victims, while maintaining the function and avoiding the contamination of in-hospital services? The suddenness of explosions and the subsequent surge of multiple victims requiring immediate medical attention prevents regional or national agencies from providing immediate medical or other management on-scene. Medical need will be greatest, and most of the victims will present during the first few hours after a blast. Local agencies will have to provide all initial management during this critical period.

One scenario for initial victim management assigns medical care to an out-of-hospital triage site designated by

the local incident commander at the scene of the event.[1] Studies of previous intentional bombings show that the vast majority of victims have minor injuries like lacerations, abrasions, or bruises.[10] With appropriate equipment available on-site, these injuries can be addressed and cared for out of hospital; any subsequently required care can follow later.[1,10] Decontamination of victims can be accomplished at the triage site, thus reducing the in-hospital spread of biohazards. Triage, decontamination, and management capabilities at an out-of-hospital site allow for appropriate triage and timely delivery of decontaminated patients to in-hospital systems in a sequence based on severity of injuries. Critically injured ("red-tag") patients can be sent first, followed by patients with intermediate needs ("yellow-tag"), and then by those with minor inuries ("green-tag"). Depending on the resources of the community, it is possible to send patients with green-tag injuries to pre-designated alternative destinations such as area hospitals or clinics that can manage decontaminated green-tag patients but not patients who are critically injured.[1] After initial on-scene interventions, some green-tag victims might require no further immediate medical attention.

Such systems work when local communities have mechanisms for providing out-of-hospital care and protocols for managing and transporting victims. Many options are available. Currently some communities have or are in the process of developing local disaster medical assistance teams (DMATS); others are situated close to federally mandated and sponsored DMAT or special operations response (SORT) teams that can provide such services. Many local fire/rescue/EMT organizations are outfitting units to decontaminate victims of weapons of mass destruction. Some hospitals are studying the feasibility of developing out-of-hospital management plans for such events, and they are collaborating with regional hospitals and care providers to develop Regional Advisory Committees that will address issues such as transport and management of mass-casualty victims.

The crucial component of local disaster or mass-casualty event planning is a unified mechanism for rapid disposition of patients. When first responders (often local law enforcement personnel who, by the nature of their job, are distributed throughout the community) recognize a mass-casualty situation, they alert and activate the "incident command" team, simultaneously establish crowd and perimeter control, and direct ambulatory victims away from the event scene. As other members of the incident command team arrive, further decisions about safe triage locations and initial patient management can begin. When local out-of-hospital patient management teams exist, they can be activated to arrive at event-designated triage sites and begin triage, initial patient care interventions, and decontamination procedures.

Hospitals need to be prepared to address patient management issues arising from a mass-casualty event. The Joint Commission on Accreditation of Healthcare Organizations (JCAHO) has established specific hazardous material ("hazmat") preparedness guidelines for hospitals (standards EC.1.2.1, EC. 1.2.3, EC.1.2.4, EC.1.3.3, EC.1.4.3, EC.1.5.4).[15] JCAHO requires hospitals to have in place plans for managing victims of hazmat exposure. Various federal laws (including OSHA 29 CFR 1910.120, 1910.1200, 1910.132) require Emergency Departments to have personnel trained and prepared to handle hazmat accidents.[15] However, it is true that most hospitals are not currently prepared to cope with a massive, simultaneous influx of victims from a mass-casualty blast or bombing.

Hospital response to intentional bombings cannot follow the usual "disaster drill" in which care providers are rushed from other areas of the hospital to provide initial care of victims, then returned to their usual jobs. In the event of biohazard contamination, such an approach will ensure widespread contamination with subsequent morbidity and possible death of care givers and other patients in the hospital. Hospitals must determine the maximum number of care providers, trained and outfitted for hazmat work, who could rapidly be available during such an event, and then develop plans for managing the large numbers of patients expected. As already noted, this is best done by preplanning with local incident response systems for initial out-of-hospital management of victims and determining what other area resources are available to handle victims of such events. Hospitals, urgent care clinics, and other providers should work proactively with area prehospital event command systems to develop plans for ultimate patient disposition.

Summary

Bombings and other blast-related events place severe demands on pre-hospital and in-hospital systems. The resulting surge of victims can overwhelm the resources of any facility not prepared for such an event. The September 11 terrorist attacks underscore the urgency of our need for preparedness. The challenges become even more daunting when there is possible hazmat exposure as well; this means that adequate and rapid disposition of victims is even more critical in order to avoid contamination of hospitals systems or whole communities.

Federal agencies have been designated and federal mandates have been issued to address mass casualty events, but federal or even regional systems cannot respond in time to address the massive and immediate needs generated by an explosion. Local communities must take the lead in developing incident command systems for initial management of such events. Hospital and pre-hospital providers play a key role in such planning. Ultimate management and disposition of large numbers of casualties, especially if contaminated, cannot follow standard patient management protocols; new protocols are needed. To avoid a total, overwhelming break

down of in-hospital resources, hospitals need to assume a lead role in addressing such issues in their local communities.

REFERENCES

1 Severance HW. Blast-related injuries: special considerations for mass-casualties management. Trauma Vue 1999;7:1-3.

2 Karmy-Jones R, Kissinger D, Golocovsky M, et al. Bomb-related injuries. Military Med 1994;159:536-9.

3 Martin TE. Resolving the casualty evacuation conflict. Injury Int J Care Injured 1993;24:514-6.

4 Miller K. Biological agents as weapons: medical implications. Fire Engineering 1999;152:83-9.

5 Sauer SW, Keim ME. Hydroxocobalamin: improved public health readiness for cyanide disasters. Ann Emerg Med 2001;37:635-41.

6 Stapczynski JS. Blast injuries. Ann Emerg Med 1982;11:687-94.

7 Gans L, Kennedy T. Management of unique clinical entities in disaster medicine. Emerg Med Clin North Am 1996;14:301-26.

8 Mellor SG. The pathogenesis of blast injury and its management. Br J Hosp Med 1988;39(6):536-9.

9 Frykberg ER, Tepas JJ. Terrorist bombings. Ann Surg 1988;208:569-76.

10 Hadden WA, Rutherford WH, Merrett JD. The injuries of terrorist bombing: a study of 1532 consecutive patients. Br J Surg 1978;65:525-31.

11 Kizer KW. Dysbarism (blast injury). In: Tintinalli JE, Kelen GD, Stapczynski JS (editors). Emergency Medicine, A Comprehensive Study Guide. 5th edition. New York: McGraw-Hill, Inc., 2000;1275-8.

12 Stapczynski S. Blast injuries. In: Harwood-Nuss AL (editor). The Clinical Practice of Emergency Medicine. 3rd edition. Philadelphia, PA: Lippincott Williams & Wilkins, 2001;616-9.

13 American College of Surgeons, Committee on Trauma. ATLS. 6th Edition. Chicago, IL: American College of Surgeons & First Impressions Publishers, 1997.

14 Smith CG, Veenhuis PE, MacCormack JN. Bioterrorism, a new threat with psychological and social sequelae. NC Med J 2000;61:150-65.

15 Levitin HW, Siegelson HJ. Hazardous materials: disaster medical planning and response. Emerg Med Clin North Am 1996;14:327-48.