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Mass Casualty Terrorist Bombings: A Comparison of Outcomes by Bombing Type

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Study objective: We compared the epidemiologic outcomes of terrorist bombings that produced 30 or more casualties and resulted in immediate structural collapse, occurred within a confined space, or occurred in open air.

Methods: We identified eligible studies of bombings through a MEDLINE search of articles published between 1966 and August 2002 and a manual search of published references. Pooled and median rates of mortality, immediately injured survival, emergency department use, hospitalization, and injury were determined for each bombing type.

Results: We found 35 eligible articles describing 29 terrorist bombings, collectively producing 8,364 casualties, 903 immediate deaths, and 7,461 immediately surviving injured. Pooled immediate mortality rates were structural collapse 25% (95% confidence interval [CI] 6% to 44%), confined space 8% (95% CI 1% to 14%), and open air 4% (95% CI 0% to 9%). Biphasic distributions of mortality were identified in all bombing types. Pooled hospitalization rates were structural collapse 25% (95% CI 6% to 44%), confined space 36% (95% CI 27% to 46%), and open air 15% (95% CI 5% to 26%). Unique patterns of injury rates were found in all bombing types.

Conclusion: Patterns of injury and health care system use vary with the type of terrorist bombing.

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INTRODUCTION

Background

Explosions are by far the most common cause of casualties associated with terrorism. Of 93 reported terrorist attacks producing more than 30 casualties in the world from 1991 to 2000, 88% involved explosions.[1] These mass casualty events not only resulted in significant death and destruction but also challenged emergency medical care systems in 27 countries.[1] The largest of these attacks were catastrophic medical disasters, generating thousands of casualties and acutely overwhelming local emergency medical and hospital resources.

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Capsule Summary

What is already known on this topic

Very little has been reported about the epidemiology and outcomes of mass casualty terrorist bombing attacks in the civilian setting.

What question this study addressed

Thirty-five published reports of terrorist bombings producing 30 or more casualties and with sufficient data on outcomes were reviewed and summarized.

What this study adds to our knowledge

Among the 8,634 casualties, most deaths were immediate (and untreatable). Both early (emergency department [ED]) and late (inhospital) mortality rates were 1% or less, ED utilization by victims ranged from 48% to 94%, and hospitalization rates ranged from 15% to 36%.

How this might change clinical practice

EDs will rarely be presented with a large influx of critical patients. Rates of ED utilization vary with the structural environment of the bombing site, allowing some prediction of ED and hospital bed capacity needs. Enhancing field care and rescue, especially for victims of structural collapse, may be important.

Goals of This Investigation

Despite the importance of terrorist bombings to contemporary emergency department (ED) and hospital disaster planning and preparedness, little has been reported about the comparative epidemiology of mass casualty terrorist bombings and the factors affecting their outcomes.[2,3] The objective of this study was to compare the epidemiologic outcomes among mass casualty terrorist bombings causing immediate structural collapse, those taking place within a confined space, and those occurring in open air, as reported in the medical literature.

METHODS

Study Design

A primary MEDLINE search was conducted with an OVID interface for articles that reported the epidemiologic outcomes of terrorist bombings and were published between 1966 and September 2002 in the English language. The keywords "bombing," "explosions," "terrorism," or "terrorist bombing" were used. The reference lists within these initially identified articles were then searched for further articles relevant to the topic.

Articles that reported the epidemiologic outcomes of terrorist bombings were retrieved through a search of their titles or abstracts. Each retrieved article was then manually examined to confirm that it met the following selection criteria: (1) the article reported 1 or more specific bombings (identified by location and year); (2) the article attributed the bombing to an act of terrorism; and (3) the article reported epidemiologic data about those specific bombings. A standardized data collection form was used to extract data.

Inclusion Criteria

We included all terrorist bombings meeting the following inclusion criteria: (1) the bombing caused 30 or more casualties; (2) the bombing produced an immediate structural collapse involving more than 1 floor of a building, occurred within a confined space containing the majority of casualties (but did not produce a structural collapse), or occurred in the open air (but did not produce a structural collapse); and (3) the bombing had sufficient epidemiologic outcome data to permit further analysis. We based the cutoff value of 30 or more casualties on the definition of "mass casualty" bombing suggested by Rignault and Deligny.[4] We based our categorization of terrorist bombings into structural collapse, confined space, and open air categories on previous comparative epidemiologic studies of confined space versus open air bombings by Leibovici et al[3] and Lynn et al[5] and on recommendations about expected outcomes in confined space and structural collapse bombings by the US Centers for Disease Control and Prevention.[6]

We excluded bombings that occurred after evacuation commenced because we anticipated that this would reduce the impact of a given bombing. We also excluded bombings that occurred in confined spaces in which the majority of victims were outside the space because we anticipated that this would obscure the effects of being inside the confined space during an explosion. We also excluded bombings in which insufficient information was provided to identify the bombing type or in which the bombing type was mixed (sharing features of >1 bombing type or a bombing occurring in addition to some other type of violence). We also excluded bombings that occurred in flying aircraft because we believed that this represents a unique mechanism of injury.

Data Collection and Processing

Each terrorist bombing meeting these inclusion criteria was analyzed further, and data about bombing characteristics and outcomes were extracted as shown in Table 1. The number of immediately surviving injured and the number of injured survivors seeking emergency care at EDs (or comparable facilities) were extracted as separate data elements. The number of injured survivors seeking emergency care in EDs and the number of hospitalized patients with specific injury types were also extracted according to the guidelines shown in Table 2. The extracted data were then tabulated by bombing type, bombing characteristics, and outcomes.

Outcome Measures and Primary Data Analysis

We combined data across the studies in 2 ways. First, we calculated pooled outcome rates with 95% confidence intervals (CIs) for each bombing type by using the random effects method described by Laird and Mosteller.[7] The outcome rates we used are defined in Table 3. We then calculated heterogeneity for each pooled outcome rate by using Fisher's exact test instead of χ^2 analysis because some data sets contained counts less than 5. When data were available only from a single study, we calculated the 95% CI for the percentage by the binomial exact method.

Second, we calculated the outcome rates in each individual bombing and then used these results to determine median outcome rates and interquartile ranges (IQRs) for each outcome according to bombing type. Calculations were performed with EXCEL (Microsoft Corporation, Redmond, WA) and STATA 7 statistical software (Stata Corporation, College Station, TX).

Data about some injury types were not available for comparison in the eligible studies, including pulmonary contusion, deafness, abrasion, contusion, sprain, strain, dislocation, open fracture, spine fracture, closed head injury, concussion, and acute psychiatric conditions.

Table 1.
Data extracted about each bombing in studies meeting the inclusion criteria.

Data Type	Data Abstracted
Bombing characteristics	Bombing type
	Target city
	Year of bombing
	Target type
	Number of explosions in event
	Explosive composition
	Use of additives: metallic (eg, nails or shrapnel) or incendiary
	Explosive weight (or magnitude)
	Use of vehicle delivery system
	Use of terrorist suicide
	Occurrence of pre-explosion evacuation
	Time of arrival of first EMS unit at-scene (min)
	Time of arrival of first injured survivor at ED or comparable facility (min)
	Time of arrival of last injured survivor at ED or comparable facility (min)
	Extrication or rescue of entrapped victims at-scene
	Time of extrication or rescue of entrapped victims at-scene (h)
	Design used in construction of bombed structure
	Materials used in construction of bombed structure
Outcomes	Number of injured
	Number of immediate deaths (at bombing site or in transport to hospital)
	Number of early deaths (<4 h after the blast in ED or hospital)
	Number of late deaths (≥4 h after the blast)
	Number of deaths
	Number of immediately surviving injured
	Number of injured survivors seeking emergency care at ED (or comparable facility)
	Number of hospitalized (or transferred to another hospital)
	Number of injured survivors seeking emergency care with specific injury
	Number of hospitalized with specific injury

EMS, Emergency medical services.

RESULTS

The primary and hand searches yielded 76 articles reporting epidemiologic outcomes of terrorist bombings.[2-4,6,8-79] Further review found that only 57 articles reported the epidemiologic outcomes of 80 specific terrorist bombings.[3,4,8-62] Detailed examination found that 50 bombings did not meet the inclusion criteria of this review (Figure).[4,23,34,42-62] Thirty-two bombings were excluded because they produced fewer than 30 casualties.[4,23,34,54,55] Five bombings were excluded because epidemiologic outcome data were insufficient.[42,51,59,61] Two open air bombings were excluded because they were associated with pre-explosion evacuation.[43,45,50] Three confined space bombings were excluded (2 inside enclosed parking garages and 1 inside a youth club building) because more than 95% of the victims were outside the spaces.[44,49,56-58,60]

Three bombings were excluded because no information was available to determine the bombing type.[23,55] Two bombings were excluded because they combined features of a confined space and an open air bombing (1 bombing occurred on a partially enclosed terrace with open walls and another occurred in a partially enclosed waiting area adjacent to a mess hall).[48,53] The 2001 New York City World Trade Center attack was excluded because of the following: (1) relevant epidemiologic outcome data were insufficient during the study period (the total number of injured was not reported, and available data were limited to injured survivors seeking emergency care at 5 Manhattan hospitals); (2) pre-explosion evacuation occurred in the case of the second tower attacked (and precollapse evacuation in the case of both towers); and (3) the bombing type was mixed (the attack actually consisted of a sequence of mass casualty events characterized by asynchronous aircraft collisions, confined space explosions, high rise structural fires, and markedly delayed structural collapses).[46,47,52]

Table 4 shows the reported characteristics of the 29 bombings meeting the inclusion criteria of this study.[3,4,8-41] The at-scene arrival time of EMS was only reported in the Oklahoma City bombing (6 minutes).[15] The extrication of entrapped victims was specifically reported in 4 structural collapse bombings and none of the confined space or open air bombings.[9,12,15,22] Specific information describing the building design or materials of bombed structures was not reported in any of the bombings.

Table 5 shows the outcomes of these bombings. These events collectively produced 8,364 casualties, killed 903 immediately, and left 7,461 immediately surviving with injuries.

Table 6 shows the pooled and median rates of immediate mortality, immediately surviving injured, ED use, early mortality, hospitalization, and late mortality for the 3 types of terrorist bombings.

Table 2.
Injury rates in ED patients by bombing type.[*]

Injury Type	Structural Collapse[†]	Confined Space[†]	Open Air[‡]	Comments
Pulmonary blast	5 (2–7) 5 (5–5)	21 (0–46)[§] 13 (4–29)	7 (4–11)[‖]	Includes pulmonary contusion, pneumothorax, pneumomediastinum, and blast lung injury
Pneumothorax	1 (1–2) 2 (1–2)	9 (0–20)[§] 7 (4–13)	3 (1–6)[‖]	Includes hemopneumothorax, pulmonary blast injury requiring tube thoracostomy
Blast lung syndrome	1 (0–3) 2 (1–2)	16 (0–37)[§] 11 (1–26)	5 (3–9)[‖]	Includes acute respiratory distress syndrome, pulmonary blast injury requiring mechanical ventilation
Tympanic membrane rupture	2 (1–4)[‖]	35 (16–54)[§] 32 (26–42)	5 (0–15) 5 (3–8)	
Intestinal perforation	1 (0–6)[‖]	3 (0–6) 4 (3–4)	0 (0–2)[‖]	
Penetrating soft tissue	66 (61–71)[‖]	41 (14–67)[§] 54 (34–54)	86 (58–100) 86 (79–93)	Includes lacerations, puncture wounds, wounds with foreign bodies
Eye	4 (1–10)[§] 2 (1–6)	6 (0–15)[§] 6 (4–8)	1 (0–3)[‖]	
Penetrating eye	2 (1–3) 2 (1–2)	2 (0–4) 2 (2–2)	1 (0–3)[‖]	Includes ruptured globe, intraocular foreign body
Penetrating abdomen	1 (0–2) 1 (1–1)	2 (0–4) 2 (2–2)	3 (0–8) 4 (2–5)	
Penetrating vascular	2 (1–3) 2 (2–3)	2 (0–5) 2 (2–3)	1 (0–3)[‖]	Includes arterial or venous injuries
Fracture	13 (11–15) 13 (13–13)	20 (0–48)[§] 21 (13–28)	6 (3–11)[‖]	Includes open fractures
Amputation	2 (0–3) 2 (2–2)	3 (0–6) 3 (2–3)	1 (0–4)[‖]	Includes digits
Intracranial	2 (1–3) 2 (2–3)	3 (0–6) 3 (2–4)	1 (0–3)[‖]	Includes open or depressed skull fracture, intracranial hemorrhage
Liver or spleen	1 (0–2) 2 (1–2)	2 (0–4) 2 (2–2)	1 (0–3)[‖]	Any mechanism
Burn	1 (1–2) 1 (1–2)	22 (16–28) 22 (21–24)	1 (0–2)[‖]	All types, including flash burns; excludes incendiary explosive devices
Inhalation	2 (1–4) 2 (2–2)	NR	NR	
Crush	3 (0–8)[§] 3 (2–5)	NR	NR	Includes compartment syndrome

NR, Not reported.
*All values are pooled percentage with 95% CI followed by median percentage with IQR.
†Total >100%, because patients may have had >1 injury.
‡Total <100%, because some patients had injury types not included here.
§*P*<.05 (heterogeneity exists among the pooled studies).
‖Data from a single study.

The pooled and median rates of injury in injured survivors seeking emergency care at hospitals (or similar facilities) are shown in Table 2. One additional eligible bombing not shown in Table 1 was used in determining the frequency of tympanic membrane ruptures in ED patients in open air bombings.[41] The pooled and median rates of injury in hospitalized victims are shown in Table 7.

LIMITATIONS

This study also has a number of limitations. First, the inclusion criterion that a mass casualty terrorist bombing must produce 30 or more casualties may seem arbitrary because some health care systems may be overwhelmed by fewer than 30 victims. Nevertheless, the simultaneous occurrence of 30 casualties will at least temporarily disrupt the capacity of most emergency care systems to respond and result in external disaster response resources being placed on alert. The use of this cutoff point led to the exclusion of only 4 bombings producing 20 to 29 casualties on the basis of quantity alone.[23,55]

Some data were incomplete. For example, the data from the 1994 Buenos Aires bombing were from 1 hospital 150 meters from the bombing site.[12] It is possible that some of the immediately injured survivors, probably with less serious injuries, sought care at other hospitals, which would in turn increase the pooled ED use rate in structural collapse bombings. In addition, some of the reported injury rates are limited by the number of reported bombings.

Some data may be inaccurate because all of the articles reviewed were retrospective case reports, which is a problem that plagues the epidemiologic analysis of nearly any type of disaster because the challenge of accurate data collection during a disaster is understandably great.

We were unable to address a number of potential confounding factors, which may have influenced the outcome rates. Such factors include the explosive magnitude, explosive composition, use of metallic or incendiary additives, use of terrorist suicide, victim proximity to the detonation point, victim density around the detonation point, building occupancy, building design or materials, occurrence of other injury-causing sequelae (eg, structural fire), and the timeliness, capacity, and quality of medical care at various stages (eg, EMS response, search and rescue).

In addition, many of the confined space and open air bombings occurred in communities with repeated experience with mass casualty terrorist bombings, possibly improving their outcomes. On the other hand, we did note a correlation between the use of a vehicle to

Table 3.
Outcome rates and definitions.

Outcome Rate	Definition
Immediate mortality rate	Number of immediate deaths/number of injured
Early mortality rate	Number of early deaths/number of injured
Late mortality rate	Number of late deaths/number of injured
Immediately surviving injured rate	Number of immediately surviving injured/number of injured
ED use rate	Number of injured survivors seeking emergency care at ED/number of injured
Hospitalization rate	Number of hospitalized/number of injured
Injury rate in ED patients	Number of injured survivors seeking emergency care with specific injury/number of injured survivors seeking emergency care at ED
Injury rate in hospitalized patients	Number of hospitalized with specific injury/number of hospitalized

Figure.
*Study flow. *One occurred on an airplane. †Eight had insufficient information to identify bombing type. ‡One had insufficient information to be included in Tables 4 and 5, but was included in Table 2.*

76 articles reporting epidemiologic outcomes of terrorist bombings

↓

57 articles reporting epidemiologic outcomes of 80 specific terrorist bombings

↓

7 terrorist bombings excluded, produced 1–9 casualties*
13 terrorist bombings excluded, produced 10–19 casualties†
12 terrorist bombings excluded, produced 20–29 casualties†
5 terrorist bombings excluded, insufficient epidemiologic data
2 terrorist bombings excluded, pre-explosion evacuation occurred
3 terrorist bombings excluded, explosion within confined space with >95% of casualties occurring outside space
3 terrorist bombings excluded, insufficient information to identify bombing type
2 terrorist bombings excluded, bombings mixed type—confined space and open air
1 terrorist bombing excluded, bombings mixed type—confined space and structural collapse
2 terrorist bombings excluded, bombings mixed type—bombings and riots combined

↓

30 terrorist bombings meeting inclusion criteria of study‡

carry the explosive charge and structural collapse (presumably because vehicles are required to carry explosives of sufficient magnitude to collapse a building).

It is also likely that publication bias exists here as well. Our search strategy excluded reports of terrorist bombings published outside of MEDLINE, including studies potentially published in foreign medical journals not included in MEDLINE or in various print media. For example, print media sources were not used, because news articles rarely report information about ED use rates or specific injury types and are never subject to scientific peer review. Such exclusions may lead to the overestimation or underestimation of the net impact of a particular bombing type.

Finally, interpretation of pooled outcome rates is limited by the degree of heterogeneity existing across the studies included within a particular bombing type. For this reason, we also presented median outcome rates and interquartile ranges.

DISCUSSION

The median number and range of injured in each bombing type reflect multiple factors, including the explosion magnitude, composition, environment, and location relative to the number of potential victims at risk. For example, in the 6 structural collapse bombings, relatively large bombs were detonated within or beside

Table 4.

Characteristics of 29 mass casualty terrorist bombings by bombing type.

City, y	Bombing Site	No. of Explosions	Explosive Composition	Additives	Magnitude, kg*	Vehicle	Suicide	Time to ED Arrival of First IS, min	Time to ED Arrival of Last IS, min	Time to Extrication of Last IS, h
Structural collapse										
Bologna, 1980[8]	Train station building	1	NR	NR	20	NR	NR	NR	90	NR
Beirut, 1983[9-11]	Housing building	1	NR	NR	5,500	Yes	NR	NR	NR	NR
Buenos Aires, 1994[12]	Office building	1	Ammonal	NR	300	Yes	NR	†	NR	36
Oklahoma City, 1995[13-17]	Office building	1	ANFO	NR	1,814	Yes	NR	20	NR	13
Dhahran, 1996[18-20]	Housing building	1	Dynamite, fuel	NR	4,500	Yes	NR	NR	NR	NR
Nairobi, 1998[21,22]	Office building	1	NR	NR	<1,814	Yes	NR	NR	NR	24–38
Confined space										
Belfast, 1972[23-27]	Restaurant	1	NR	NR	2	NR	NR	NR	NR	NR
London, 1974[28-30]	Museum	1	NR	NR	5	NR	NR	20	NR	NR
Guildford, 1974[28,29]	Pub	1	NR	NR	5	NR	NR	NR	NR	NR
Birmingham, 1974[28,29,31,32]	Pubs	2	NR	NR	NR	NR	NR	NR	NR	NR
Paris, 1985[4]	Building interior	1	NR	I	NR	NR	NR	NR	NR	NR
Berlin, 1986[33,34]	Night club	1	NR	NR	5	NR	NR	NR	NR	NR
Paris, 1986[4]	Building interior	1	NR	NR	NR	NR	NR	NR	NR	NR
Paris, 1986[4]	Building interior	1	NR	NR	NR	NR	NR	NR	NR	NR
Paris, 1986[4]	Building interior	1	NR	NR	NR	NR	NR	NR	NR	NR
Paris, 1986[4]	Building interior	1	NR	NR	NR	NR	NR	NR	NR	NR
Jerusalem, 1988[35]	Bus	1	NR	NR	6	NR	NR	NR	NR	NR
Jerusalem, 1996[3*]	Bus	1	Antitank mine	M	NR	NR	Yes	NR	NR	NR
Jerusalem, 1996[3*]	Bus	1	Antitank mine	M	NR	NR	Yes	NR	NR	NR
London, 1999[36]	Pub	1	NR	M	NR	NR	NR	38	143	NR
Open air										
Saigon, 1966[37]	Street	1	Plastique	NR	227	Yes	NR	NR	180	NR
Belfast, 1971[23]	Street	1	NR	NR	NR	NR	NR	NR	NR	NR
Belfast, 1972[23]	Street	1	NR	NR	NR	NR	NR	NR	NR	NR
Belfast, 1972[23]	Street	1	NR	NR	NR	NR	NR	NR	NR	NR
London, 1973[28,29,38]	Street	1	NR	NR	NR	Yes	NR	5	70	NR
London, 1991[39]	Train station platform	1	Semtex	NR	2	NR	NR	16	45	NR
Tel Aviv, 1995[40]	Street	1	NR	NR	10	NR	Yes	15	NR	NR
Jerusalem, 1996[3*]	Bus station	1	Antitank mine	M	NR	NR	Yes	NR	NR	NR
Jerusalem, 1996[3*]	Trading center	1	Antitank mine	M	NR	NR	Yes	NR	NR	NR

IS, Injured survivor; **NR,** not reported; **ANFO,** ammonium nitrate fuel oil; **I,** incendiary; **M,** metallic.

*TNT equivalent when composition not reported.

†ED only 150 m from site.

structures containing large numbers of potential victims. Because these explosions tended to be quite large, potential victims outside the target structure were also at risk. In confined space bombings, smaller bombs were detonated within small-volume structures (eg, buses or rooms) containing fewer potential victims. Consequently, casualties were rarely reported outside the confined space. In open air bombings, bombs of variable magnitude (but typically less than those in structural collapse) were detonated outside (eg, street or shopping area) amid variable numbers of potential victims, who in most cases were relatively dispersed around the detonation point.

The pooled immediate mortality rates also reflect these underlying mechanisms: 1 of 4 victims died immediately in structural collapse bombings, 1 of 12 died immediately in confined space bombings, and 1 of 25 died immediately in open air bombings.

Early mortality rates were low in this study. In particular, only 3 early deaths were reported in 13 confined space and open air bombings combined. Because EDs are rarely confronted with many simultaneously dying patients, emergency physicians should rarely be forced to withhold resuscitative efforts from moribund survivors, except in events that generate catastrophic numbers of casualties or occur in locations with extremely limited emergency medical resources.

Late mortality rates were also relatively low in this study. Late mortality rates are influenced by a number of factors, including the burden of victims with life-

Table 5.
Outcomes of 29 mass casualty terrorist bombings by bombing type.

City, y	Injured	Immediate Deaths	Early Deaths	Late Deaths	Total Deaths	Immediately Surviving Injured	Used ED	Hospitalized
Structural collapse								
Bologna, 1980[8]	291	73	1	10	84	218	218	181
Beirut, 1983[9-11]	346	234	0	7	241	112	97	85
Buenos Aires, 1994[12]	286	79	3	4	86	207	86	39
Oklahoma City, 1995[13-17]	759	163	2	3	168	596	438	85
Dhahran, 1996[18-20]	519	19	NR	NR	NR	500	NR	NR
Nairobi, 1998[21,22]	4,257	213	NR	NR	NR	4,044	NR	524
Median	433					359		85
Confined space								
Belfast, 1972[23-27]	83	2	0	0	2	81	81	25
London, 1974[28-30]	37	0	1	0	1	37	37	19
Guildford, 1974[28,29]	67	5	0	0	5	62	NR	24
Birmingham, 1974[28,29,31,32]	140	19	1	1	21	121	NR	42
Paris, 1985[4]	35	0	NR	NR	NR	35	NR	NR
Berlin, 1986[33,34]	263	2	0	1	3	261	NR	NR
Paris, 1986[4]	30	2	NR	NR	NR	28	NR	NR
Paris, 1986[4]	41	0	NR	NR	NR	41	NR	NR
Paris, 1986[4]	52	1	NR	NR	NR	51	NR	NR
Paris, 1986[4]	58	7	NR	NR	NR	51	NR	NR
Jerusalem, 1988[35]	58	3	0	3	6	55	55	29
Jerusalem, 1996[3*]	93	41	0	5	46	52	52	40
Jerusalem, 1996[3*]								
London, 1999[36]	61	2	0	0	2	59	59	9
Median	58					53		25
Open air								
Saigon, 1966[37]	141	1	NR	NR	1	140	123	NR
Belfast, 1971[23]	57	0	NR	NR	NR	57	57	2
Belfast, 1972[23]	127	4	NR	NR	NR	123	123	17
Belfast, 1972[23]	54	0	NR	NR	NR	54	54	6
London, 1973[28,29,38]	160	0	1	0	1	160	160	19
London, 1991[39]	51	1	0	0	1	50	47	NR
Tel Aviv, 1995[40]	94	18	NR	NR	NR	76	76	NR
Jerusalem, 1996[3*]	204	14	0	1	15	190	190	73
Jerusalem, 1996[3*]								
Median	94					76		18

NR, Not reported.
*Not included in median determinations (combined results from 2 events).

threatening injuries on hospitals, the burden imposed by the inappropriate hospitalization of some injured survivors (overtriage), and the capacity of hospitals to provide essential resources.[2]

The net result of these mortality rates is a biphasic distribution of death—a high immediate mortality rate, followed by low early (ED) and late (inhospital) mortality rates—in all 3 types of mass casualty terrorist bombings, which contrasts with the triphasic distribution of death described in victims of conventional blunt and penetrating trauma.[80] Possible reasons for this biphasic pattern of mortality include the unique mechanism of explosion itself, which instantaneously killed numerous victims or ineffective or delayed out-of-hospital care during these events, which led to more victims dying on-scene.

The ED use rates here suggest that virtually all immediately surviving injured went to EDs in confined space and open air bombings, whereas a substantial fraction of injured survivors did not in structural collapse bombings. A possible reason for this discrepancy is that some injured survivors in structural collapse bombings may have sought emergency care at locations other than EDs, such as clinics or private physicians' offices (ie, 27% in Oklahoma City).[14] It is conceivable that some injured survivors who were in structural collapse bombings and had relatively minor injuries may have rationally elected to avoid EDs they perceived as being overwhelmed with other victims. This discrepancy may also be caused by differences in the methodologies used to collect data in the structural collapse bombings versus the other types of bombings.

Table 6.
Outcome rates by bombing type.[*]

Outcome	Structural Collapse	Confined Space	Open Air
Immediate mortality	25 (6–44)[†] 23 (9–27)	8 (1–14)[†] 3 (1–7)	4 (0–9)[†] 1 (0–4)
Immediately surviving injured	75 (56–94)[†] 77 (73–91)	92 (86–99) 97 (93–99)	96 (91–100) 99 (96–100)
ED use	48 (25–70)[†] 44 (29–62)	89 (73–100) 97 (95–98)	94 (89–99) 95 (91–100)
Early mortality	0 (0–1) 0 (0–0)	0 (0–1) 0 (0–0)	0 (0–1) 0 (0–0)
Hospitalized	25 (6–44)[†] 14 (12–25)	36 (27–46)[†] 36 (30–47)	15 (5–26)[†] 12 (11–13)
Late mortality	2 (1–3)[†] 2 (1–2)	1 (0–3)[†] 0 (0–2)	1 (0–1) 0 (0–0)

[*]Values are pooled percentage with 95% CI followed by median percentage with IQR.
[†]$P<.05$ (heterogeneity exists among the pooled studies).

The data suggest that hospitalization rates tended to be higher in confined space bombings. Higher hospitalization rates in confined space bombings may be caused by occurrence of relatively more victims with injuries requiring inhospital intervention or observation. It may also be magnified by the inclusion of 3 bus bombings in Israel and the exclusion of several non–bus bombings in which the data were insufficient.[3,35]

Injury rates in ED and hospitalized victims reflect the need for ED and hospital resources, including types of beds, equipment, supplies, medications, and types of required specialty care (Tables 2 and 7). Virtually all injury types occurred in all bombing types, including primary blast injuries (pulmonary, auditory, and abdominal), serious penetrating injuries (ocular, abdomi-

Table 7.
Injury rates in hospitalized patients by bombing type.[*]

Injury Type	Structural Collapse[†]	Confined Space[†]	Open Air[†]
Pulmonary blast	10 (5–15) 11 (10–12)	42 (5–78)[§] 38 (24–56)	7 (0–19) 0 (0–9)
Pneumothorax	6 (3–9) 7 (5–7)	14 (0–28) 14 (7–9)	3 (0–8) 0 (0–3)
Blast lung syndrome	4 (1–6) 5 (3–5)	20 (1–38)[§] 8 (6–31)	4 (0–11) 0 (0–3)
Tympanic membrane rupture	14 (8–22)[‡]	50 (37–64) 45 (40–53)	8 (0–24)[§] 0 (0–8)
Intestinal perforation	3 (0–13)[‡]	6 (0–11) 6 (5–6)	3 (0–9)[§] 0 (0–3)
Penetrating soft tissue	63 (44–82) 63 (58–68)	48 (31–66) 52 (46–60)	57 (24–90) 50 (31–76)
Penetrating eye	6 (0–15)[§] 6 (4–9)	5 (0–12) 5 (5–5)	0 (0–10) 0 (0–0)
Penetrating abdomen	3 (0–6) 3 (3–4)	5 (0–12) 5 (5–5)	6 (0–19) 7 (3–10)
Penetrating vascular	9 (4–14) 9 (8–9)	10 (1–32)[‡]	8 (0–17) 7 (3–11)
Fracture	45 (40–51) 45 (43–48)	29 (20–39) 29 (27–30)	20 (0–40) 16 (11–28)
Amputation	3 (0–7) 4 (3–5)	3 (0–18)[‡]	0 (0–10) 0 (0–0)
Intracranial	10 (5–14) 10 (8–12)	8 (0–16) 8 (6–9)	0 (0–9) 3 (2–5)
Liver or spleen	3 (1–5) 4 (3–4)	9 (3–15) 5 (5–9)	2 (0–5) 1 (1–4)
Burn	14 (1–26)[§] 8 (7–17)	45 (35–56) 48 (39–55)	11 (0–31)[§] 0 (0–5)
Inhalation	3 (0–13)[‡]	NR	0 (0–7) 0 (0–0)
Crush	13 (4–27)[‡]	NR	0 (0–10) 0 (0–0)

NR, Not reported.
[*]Values are pooled percentage with 95% CI followed by median percentage with IQR.
[†]Total >100% because patients may have had >1 injury.
[‡]Data from a single study.
[§]$P<.05$ (heterogeneity exists among the pooled studies).

nal, and vascular), solid abdominal organ injuries (liver or spleen), and serious intracranial injuries (open or depressed skull fractures, intracranial hemorrhage). This pattern suggests that emergency physicians should be prepared to treat all types of blast injuries regardless of the bombing mechanism. Despite these similarities, a number of useful patterns emerge.

ED and hospitalized patients in structural collapse bombings also experienced inhalation injuries and crush injuries because of the structural collapse itself. Hospitalized patients in structural collapse bombings tended to have high rates of fractures, which may have also been caused by the mechanism of structural collapse.

ED and hospitalized patients in confined space bombings tended to have higher rates of pulmonary blast injuries, pneumothorax, blast lung syndrome, and tympanic membrane rupture, which is consistent with the mechanism of confined space explosions, in which victims tend to be concentrated around the detonation point and are thereby exposed to greater peak blast overpressures. Primary blast injuries are further exacerbated by the reflection of blast waves off surrounding walls, which add geometrically to produce augmented blast overpressures. ED and hospitalized patients in confined space bombings also had a higher rate of burns, which is consistent with the mechanism of flash burns that occur by virtue of greater victim proximity to blast heat.[28] In addition, hospitalized patients in confined space bombings tended to have a higher rate of hepatic or splenic injury, suggesting that solid organ injury in this setting may have been caused by not only tertiary blast effects but also primary blast injury.

ED patients in open air bombings appear to have had a higher rate of penetrating soft tissue injury because of shrapnel. The vast majority of this secondary injury was relatively minor, having been treated without hospital admission, as suggested by the lower rate of penetrating soft tissue injuries in hospitalized patients. The higher-than-expected rates of pulmonary blast injury, intestinal perforation, and burns in hospitalized victims of open air bombings are probably caused by the data stemming from 3 open air suicide bombings in Israel in which explosions occurred in the midst of dense crowds.[3,40]

What are the overall implications of these bombing types for hospital disaster management? As Table 5 suggests, structural collapse mass casualty bombings tend to produce hundreds to thousands of immediately surviving injured (median 359) and fewer than 500 hospitalized victims (median 85). Confined space mass casualty bombings tend to produce 30 to 100 immediately surviving injured (median 53) and fewer than 50 hospitalized victims (median 25). Open air mass casualty bombings tend to produce 50 to 150 immediately surviving injured (median 76) and fewer than 50 hospitalized victims (median 18). These epidemiologic patterns suggest that once a terrorist bombing is under way, knowledge of the bombing type may help guide the initial estimates of the need for ED and hospital bed capacity. Other factors must also be considered, including hospital proximity to the blast site and primary distribution of victims to other hospitals.

In addition, anticipation of injury rates in patients seeking emergency care at hospitals may help guide initial estimates of which resources will be required. For example, structural collapse mass casualty bombings tend to produce hundreds of victims with relatively high rates of injuries requiring wound care (penetrating soft tissue injuries) and orthopedic care (fractures, amputations), and relatively low rates of injuries requiring chest tubes (pneumothorax) or endotracheal intubation (blast lung syndrome). When seriously injured victims are distributed among 4 to 5 hospitals, as would typically happen in most large US cities, then it is unlikely that any single facility will have to treat more than a handful of victims requiring these critical interventions.[14,47,50,60] Confined space bombings, on the other hand, tend to produce a fraction of the immediately surviving injured seeking emergency care, with a relatively higher rate of injuries requiring tube thoracostomy, intubation, and orthopedic care and a somewhat lower percentage of injuries requiring wound care. Open air bombings tend to produce a predominant need for wound care, with a few victims with more serious injuries seeded into virtually every category.

Although it is more efficient to adopt an "all-hazards" approach when dealing with disasters, a rational strategy for managing the consequences of terrorist bombings also incorporates what is already known about mass casualty terrorist bombings into the basis for planning and preparedness. Responding to different types of mass casualty terrorist bombings should be viewed no differently than responding to different types of disasters. Although the foundation of planning and preparedness may be similar for all types, the urgency of appropriate response demands that responding physicians and emergency managers have some fundamental understanding of the most likely epidemiologic impact of each bombing type.

In conclusion, the 3 types of mass casualty terrorist bombings—structural collapse, confined space, and open air—produce unique patterns of mortality, immediately surviving injured, hospitalization, and injury rates in injured survivors. Understanding the epidemiologic patterns associated with these major types of mass casualty terrorist bombings may assist ED and hospital disaster response.

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