

Bombings: Injury Patterns & Care



Version 2.0

About the project

- This project was funded by the Centers for Disease Control & Prevention (CDC) under Cooperative Agreement, U17/CE001238-02, Terrorism Injuries: Information, Dissemination, & Exchange (TIIDE)

TIIDE partners

- American College of Emergency Physicians
- American College of Surgeons
- American Medical Association
- American Trauma Society
- National Association of County & City Health Officials
- National Association of EMS Physicians

TIIDE partners

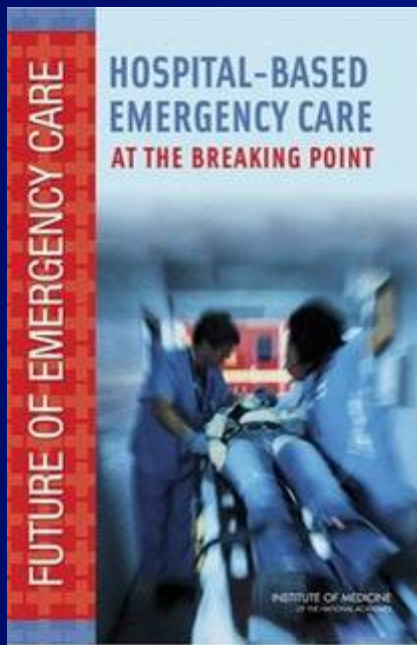
- National Association of EMTs
- National Association of State EMS Officials
- National Native American EMS Association
- Southern Nevada Health District
- State & Territorial Injury Prevention Directors Association

Objectives

- Discuss the current global context of bombings
- Describe the four categories of blast injury
- Discuss the management & care of blast casualties

Bombings: **Context,** **Injury Patterns,** **& Care**

Institute of Medicine, 2006



Explosions are by far the most common cause of casualties associated with terrorism

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Threat Assessment 2007

Use of a conventional explosive continues to be the most probable al-Qa'ida attack scenario

John Negroponte

Director of National Intelligence

Annual Threat Assessment of the Intelligence Community

Senate Select Committee on Intelligence

11 January 2007

Threat Assessment 2008

We judge use of a conventional explosive to be the most probable al-Qa'ida attack scenario because the group is proficient with ... improvised explosive devices & is innovative in creating capabilities & overcoming security obstacles

J Michael McConnell

Director of National Intelligence

Annual Threat Assessment of the Intelligence Community

Senate Select Committee on Intelligence

5 February 2008

Threat Assessment 2009

Conventional weapons & explosives will continue to be the most often used instruments of destruction in terrorist attacks

Dennis C. Blair
Director of National Intelligence
Annual Threat Assessment of the Intelligence Community
Senate Select Committee on Intelligence
12 February 2009

Global perspective

- India, 2008
- Pakistan, 2008
- Peru, 2008
- Israel, 2006
- United Kingdom, 2005
- Spain, 2004



Reuters/Prashanth Vishwanathan

20 years in US (1983-2002)

- >36,000 bombing incidents
- >5,900 injured, 699 dead



Photo courtesy of the City of Oklahoma City

“Predictable surprise”

- Tendency to maintain the status quo
- Problem exists that will not solve itself
- Problem is getting worse
- Solving the problem incurs present costs with delayed benefits

Bazerman and Watkins, Predictable Surprises, 2004

How prepared are we?

None of the hospitals surveyed in the 7 cities had sufficient emergency care capacity to respond to an attack generating the number of casualties that occurred in Madrid

*Hospital Emergency Surge Capacity:
Not Ready for the “Predictable Surprise”
Committee on Oversight & Government Reform
US House of Representatives, May 2008*

How sick are bombing injured?

Table 1-5

Characteristics of Victims of Terrorist Bombings and of Conventional Trauma^a

Variable	Terrorist Bombings (%)	Other Trauma (%)
ISS >15	28.7	10.0
GCS <6	9.5	2.9
Admission BP<90mmHg	6.2	2.5
ICU admission	26.0	7.1
Body regions injured ≥3	28.3	6.2
Surgical procedure	50.8	36.6
In-hospital mortality	6.1	2.0

^aAdapted from Kluger, Y., Peleg, K., Daniel-Aharonson, L. & Mayo, A. (2004). The special injury pattern in terrorist bombings. *Journal of the American College of Surgeons* 199, 875–879.

This table was published in "Explosion & Blast Related Injuries," Elsayed & Atkins, 2008, ©Elsevier

Bombings: Context, Injury Patterns, & Care

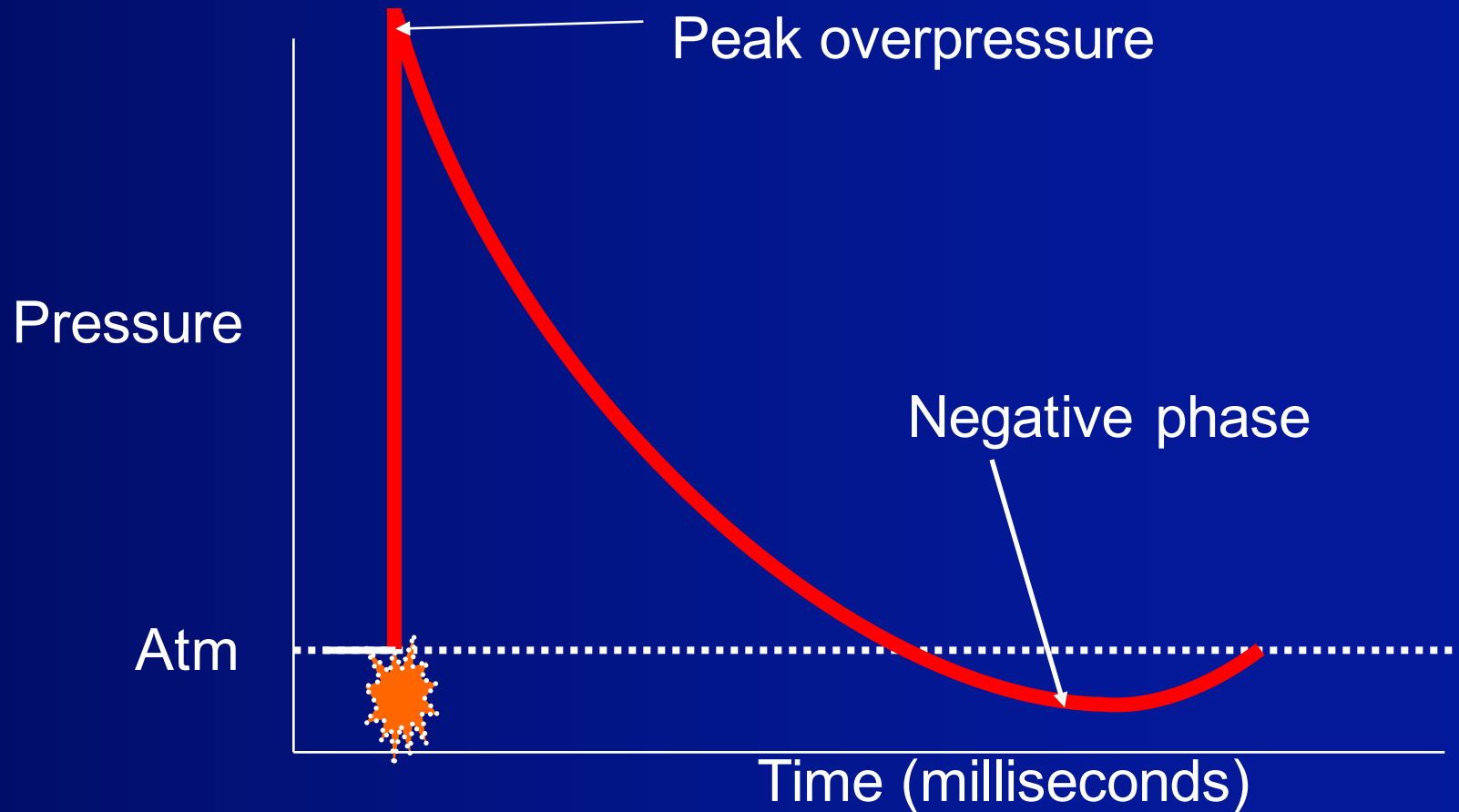
Explosives

- High-order explosives (HE)
 - Ammonium nitrate/fuel oil (ANFO)
 - Nitroglycerin (NTG)
 - Trinitrotoluene (TNT)
 - C4
- Low-order explosives (LE)
 - Gunpowder/black powder

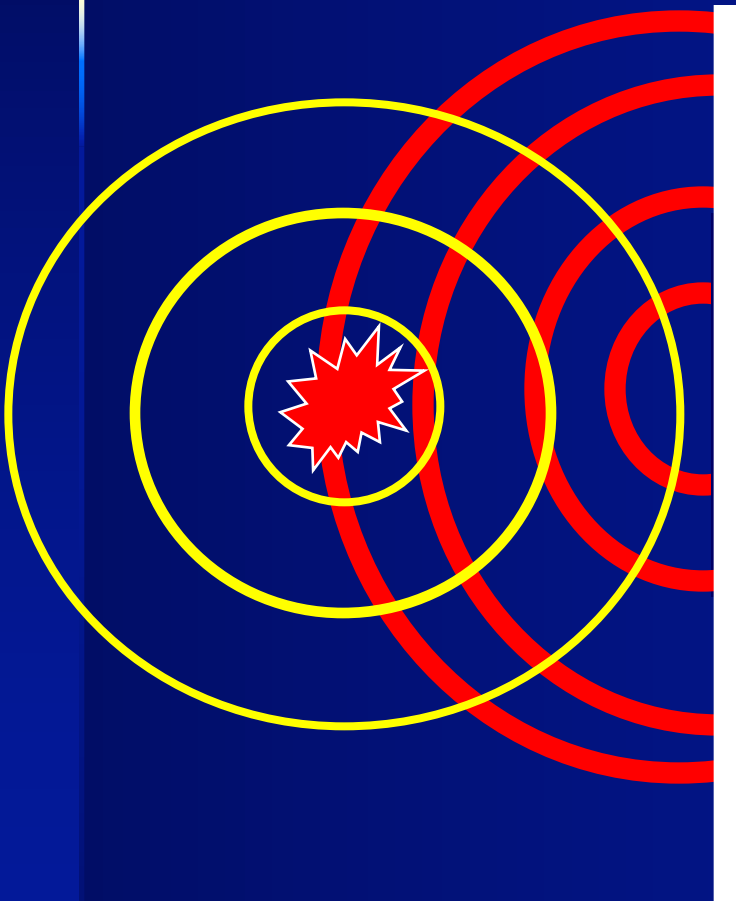
High energy explosions

- Sudden release of energy
- Solid to gas transformation
- Expands outward at supersonic speeds
- Compresses surrounding medium

Ideal blast waveform

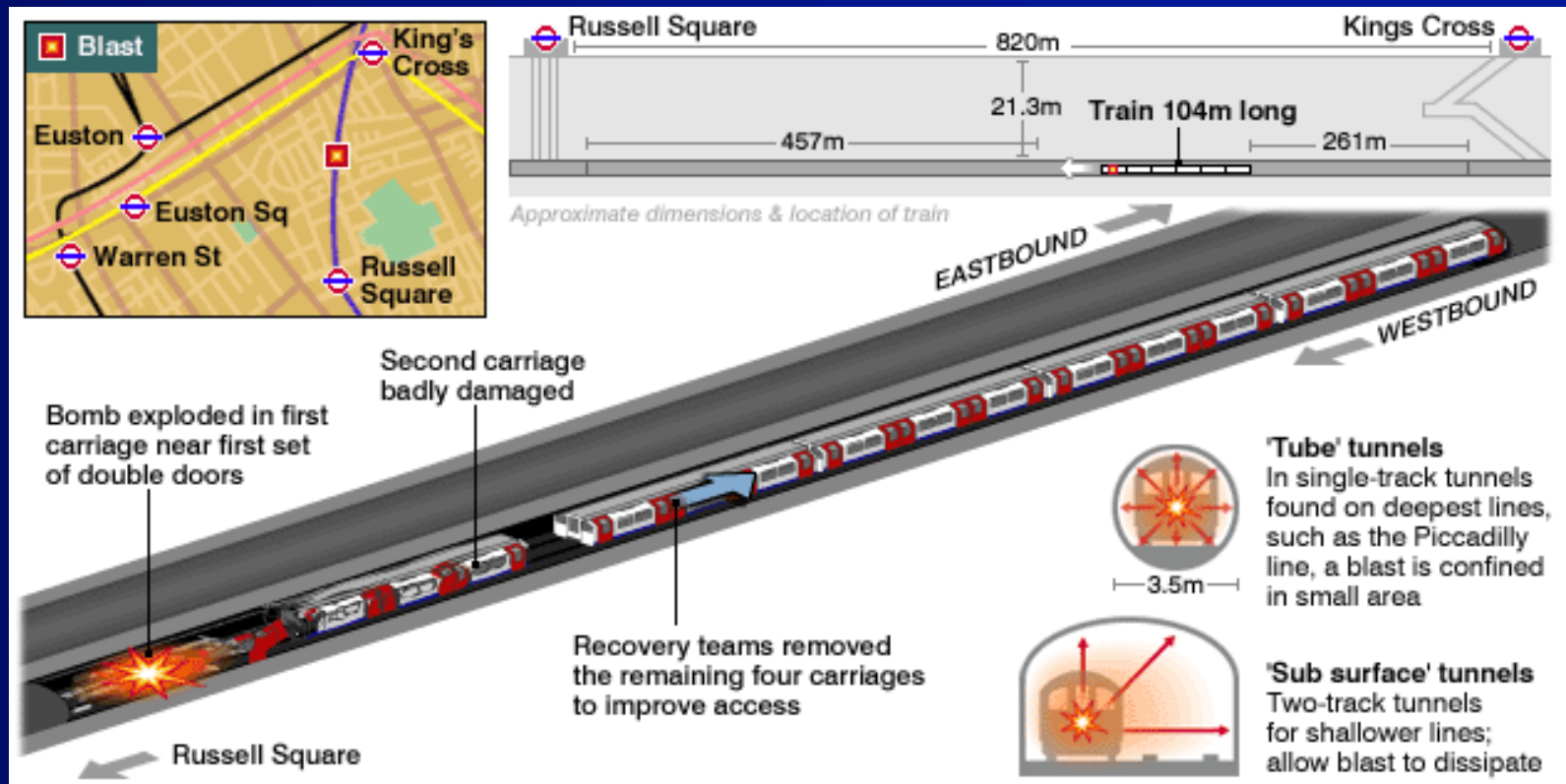


Waves & surfaces



- Surfaces amplify waves
- Reflected > incident wave strength

United Kingdom, 2005



With permission of Directorate of Public Affairs, Metropolitan Police Service, London

Blast injury categories

- Primary
- Secondary
- Tertiary
- Quaternary
- Quinary (?)

Primary blast

- Unique to high-order explosives
- Tissue injury from overpressure wave
- Major effect at air-fluid interfaces
 - Gas containing structures at risk

Blast overpressure wave



Stuhmiller J, Phillips Y, Richmond D, The Physics & Mechanisms of Primary Blast Injury, Textbook of Military Medicine, Conventional Warfare: Ballistic, Blast, & Burn Injuries, Department of the Army, Office of The Surgeon General, Borden Institute, 1991, p. 243

Primary blast injuries

- Pulmonary injury
 - Tearing, hemorrhage, edema
- Auditory injury
 - Tympanic membrane rupture
- Abdominal injury
 - Perforation, hemorrhage
- Traumatic brain injury (TBI)

Secondary blast injury

- Most common injury
- Penetrating fragments
 - Explosive debris
 - Implanted screws & nails
 - Human remains
 - Environment made airborne



Photo courtesy of US Army

Tertiary blast injury

- Displacement of casualty against blunt or sharp objects
 - Blunt injuries
 - Impalement
- Traumatic amputations



DeshGujarat.Com/Japan K Pathak

Quaternary blast injuries

- Burns
- Crush
- Eye irritation
- Exacerbations
 - Asthma
 - COPD
 - Angina



DeshGujarat.Com/Japan K Pathak

Quinary blast injury (?)

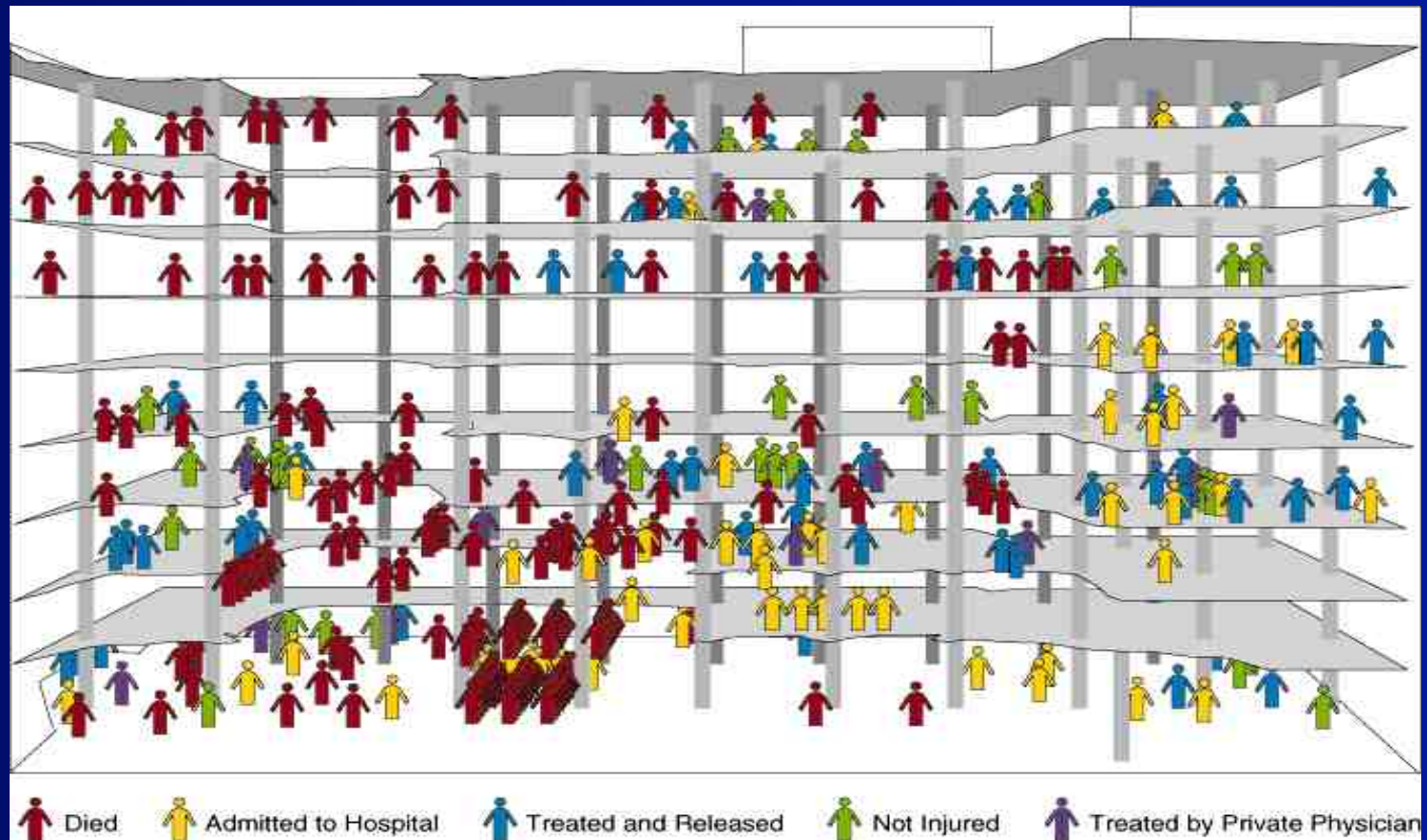
- Contamination
 - Additives
 - Industrial

<https://blastinjuryresearch.amedd.army.mil/about.cfm>

Blast injury severity

- Type & amount of explosive
 - Characteristics of pressure wave
- Casualty location in relation to blast
 - $1 / r^3$
- Environment
 - Open vs. closed space, barriers
 - Structural collapse

Murrah Federal Building injuries



JAMA, August 1996, 276 (5): 382-387 © 1996 American Medical Association

Bombings: Context, Injury Patterns, & Care

Blast lung injury

- Respiratory distress & hypoxia
- Severe pulmonary contusion
 - Direct alveolar & vascular injury
 - Hemorrhage & edema
- Associations
 - Pneumo/hemothorax
 - Bronchopleural fistula
 - Air embolism

Blast lung injury

- Occurs at 50-80 PSI
- Incidence
 - <10% casualties seen
 - 30-60% admitted casualties
- ↑ with enclosed space events

Blast lung injury



Used with permission of CHEST, December 1999; 116(6): 1683-1688

Blast lung injury

- Manage as major pulmonary contusion
 - High flow oxygen
 - Chest decompression for PTX/HTX
 - Balanced fluid resuscitation
 - Intubation/mechanical ventilation
- Disposition: monitored/ICU setting

Blast lung injury

- Significant scene mortality
- Critically injured survival >70%
- Near-normal lung function at 1 year

Blast auditory injury

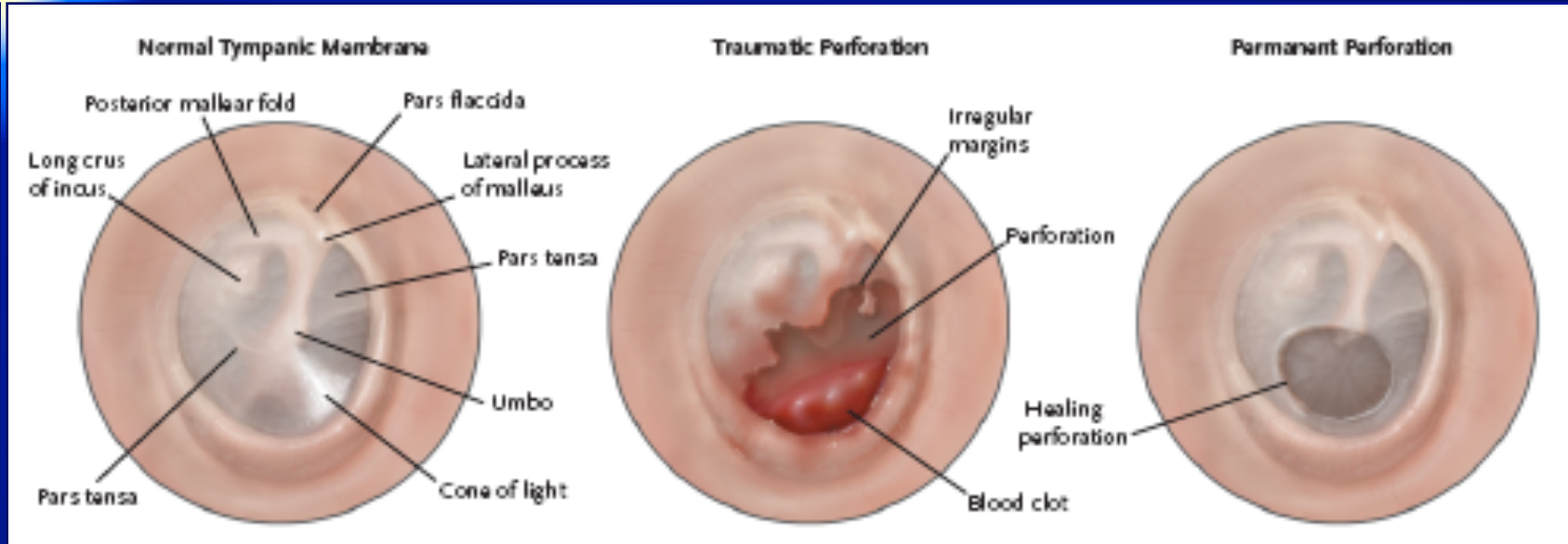
- External ear amputation = death
- Middle ear
 - Ruptured tympanic membrane most common blast injury
- Inner ear
 - Stunned receptors & sensorineural hearing loss

Tympanic membrane rupture

- ≥ 5 PSI
- Acute hearing loss, tinnitus, otalgia
- Marker for primary blast exposure
- Imperfect correlation with more significant blast injuries

Blast Injuries: Ear Blast Injuries. www.emergency.cdc.gov/masscasualties/blastinjury-ear.asp

TM rupture



With permission of NEJM, April 2005; 352: 1335—1342

TM rupture management

- Keep clean and dry
- Refer to ENT
 - Careful suctioning of debris, blood, & cerumen
 - Antibiotic eardrops
 - Follow-up for resolution

Blast gastrointestinal injury

- Colon most commonly injured
 - Acute perforation
 - Mesenteric avulsion with delayed perforation
- Risk of delayed clinical presentation
- Manage as acute abdomen

Wightman JM, Gladish SL. *Ann Emerg Med* 2001; 37(6):664-678.

Blast (traumatic) brain injury

- Concussive injury without direct blow to head
- Headache, fatigue, & poor concentration
 - May have delayed presentation
 - ? link to post-traumatic stress disorder

Explosions & Blast Injuries: A primer for clinicians. <http://emergency.cdc.gov/masscasualties/explosions.asp>

Secondary & tertiary injuries

- Fragments follow unpredictable paths through body
- All wounds dirty
 - No primary closure
 - Consider broad spectrum antibiotics
- External signs may be tip of iceberg: follow-on radiographic survey

Multi-dimensional injury

- Combined mechanisms of blast injury
 - Each casualty may have primary + secondary + tertiary + quaternary injuries
- Complex management & exponential increase in care resources

Kluger Y, Peleg K, Daniel-Aharonson L, Mayo A. The special injury patterns in terrorist bombings. *J Am Coll Surg.* 2004; 199(6); 875-879.

Multi-dimensional injury



Photo courtesy of Michael Stein, MD

Lessons from war

- Aggressive hemorrhage control
 - Tourniquets
 - Hemostatic dressings
- Avoid hypothermia
- Controlled resuscitation
- Damage control procedures

Special considerations

- Pregnancy
- Children
- Older adults
- Communication barriers
- Mental health consequences
- Postexposure prophylaxis

Pregnancy

- Placental abruption with primary blast
- 2nd/3rd trimester
 - Continuous fetal monitoring
 - Screen for fetal-maternal hemorrhage
- OB/GYN consultation

DePalma, et. al., *NEJM*, 2005; 352:1335-1342

Children

- Communication & separation
- Anatomic & physiologic differences
- Head, fractures, & amputations
 - Mortality from trunk injuries
- Resource intensive/sicker
 - Regional pediatric trauma centers

Blast Injuries: Pediatrics. www.emergency.cdc.gov/masscasualties/blastinjury-pediatrics.asp

Older adults

- ↑ orthopedic injuries
- Poor tolerance of blunt chest trauma
- Mobility limitations
- Quaternary injuries

Blast Injuries: Older Adults. www.emergency.cdc.gov/masscasualties/blastinjury-olderadults.asp

Communication barriers

- Multiple languages in multi-cultural population
- Antecedent deaf & chronic hearing loss
- Hearing impairment from blast

Mental health consequences

- Risk factors
 - Little or no warning/unknown duration
 - Potential threat to personal safety
 - Unknown health risks
- Responders & receivers at risk
- Acute stress reactions

Blast Injuries: Mental Health. www.emergency.cdc.gov/masscasualties/blastinjury-bombings-mentalhealth.asp.

HBV, HCV, & HIV postexposure?

Risk category	HBV*	HCV†	HIV§
Category 1. Penetrating injuries or nonintact skin exposures [‡]	Intervene	Consider testing	Generally no action
Category 2. Mucous membrane exposures**	Intervene	Generally no action	Generally no action
Category 3. Superficial exposure of intact skin ^{††}	No action	No action	No action

Chapman LE, Sullivent EE, et al. Recommendations for Postexposure Interventions to Prevent Infection with Hepatitis B Virus, Hepatitis C Virus, or Human Immunodeficiency Virus, & Tetanus in Persons Wounded During Bombings and Other Mass-Casualty Events --- United States, 2008, Centers for Disease Control & Prevention, MMWR, August 1, 2008 ,57(RR06);1-19

Bombings: **Context Redux,** **Injury Patterns,** **& Care**

Oklahoma City, 1995



Photo courtesy of the City of Oklahoma City

- 169 dead, >800 injured
- >65% not transported by EMS
- >60% went to hospitals within 1.5 miles of event
- Significant bystander rescue efforts

Hogan DE, et. al., *Ann Emer Med*, 1999 ; 34(6): 160-68

Madrid, 2004



Corbis

- 10 detonations on 4 trains
- 177 dead at scene
- >2000 injured
 - >50% went to 2 hospitals
 - 15 hospitals available
 - 312 casualties at GMUGH
 - 272 in 2.5 hours

Gutierrez de Ceballos, et. al., *Crit Care Med*, 2005 Jan; 33 (1 Suppl): S107-12

Scene principles

- Protect responders
 - Anticipate secondary events
 - Appropriate PPE
 - Activate incident command
- Protect the public
- Protect casualties
- Protect crime scene



Photo courtesy of the
Oklahoma City National
Memorial & Museum

ED as scene



DeshGujarat.Com/Japan K Pathak

Mass casualty triage

- Significant initial bystander involvement



AP/Khalil Senosi

- Casualties self-triage to closest facility
 - Surge of non-critical followed by critical
 - Limited EMS triage

Auf der Heide E, *Ann Emerg Med.* 2006, 47(1), 34-49.

Mass casualty triage

- Greatest good for greatest number
- Repeated across casualty settings
- Majority not critically injured
 - Critically injured have complex, multidimensional injuries

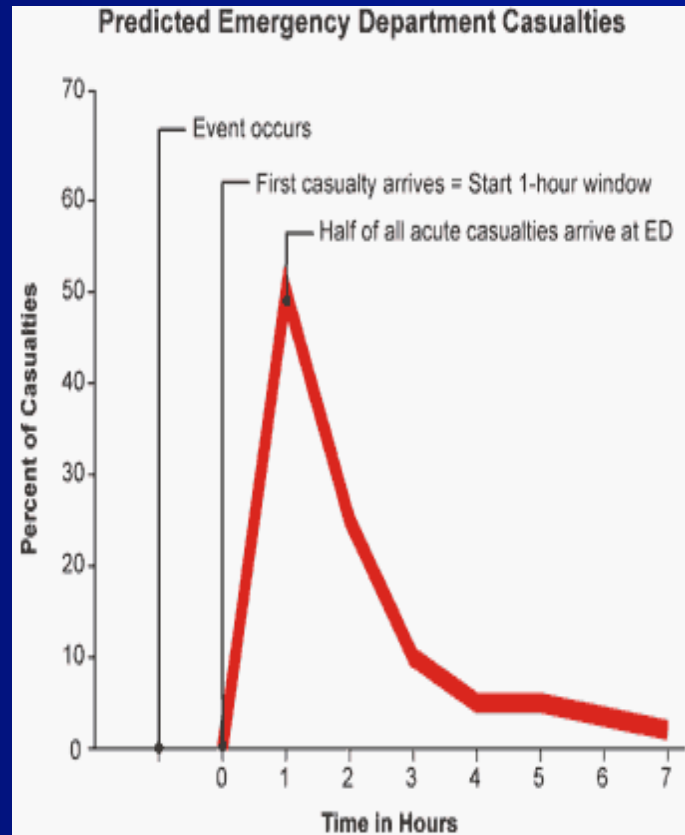
Are there patterns?

Table 1-3 Patterns of Death, Hospitalizations, and Outpatient Treatment following a Bombing Event

Author	Total Injured No.	Deaths No. (%)	Admitted No. (%)	Outpatient No. (%)
Mallonee et al., 1996	759	167 (22)	83 (11)	509 (67)
Thompson, Brown, Mallonee & Sunshine, 2004	420	19 (5)	66 (16)	335 (80)
Cooper, Maynard, Cross & Hill, 1983	385	28 (7)	104 (27)	253 (66)
Frykberg & Tepas, 1988	3357	423 (13)	881 (26)	2053 (61)
Biancolini, Del Bosco & Jorge, 1999	286	84 (29)	41 (14)	161 (56)

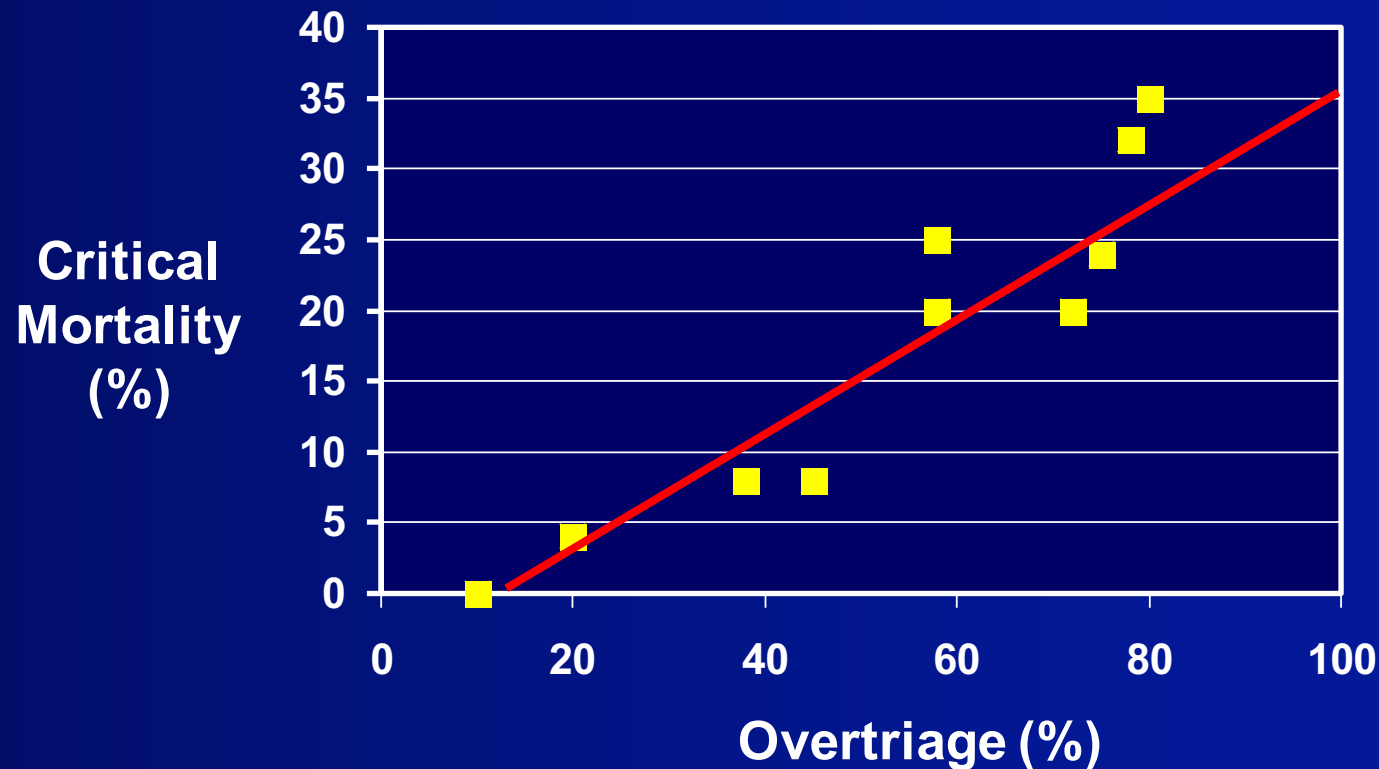
This table was published in "Explosion and Blast Related Injuries", Elsayed & Atkins, 2008, ©Elsevier

Simplified casualty predictor



<http://emergency.cdc.gov/masscasualties/predictor.asp>

Overtriage & critical mortality

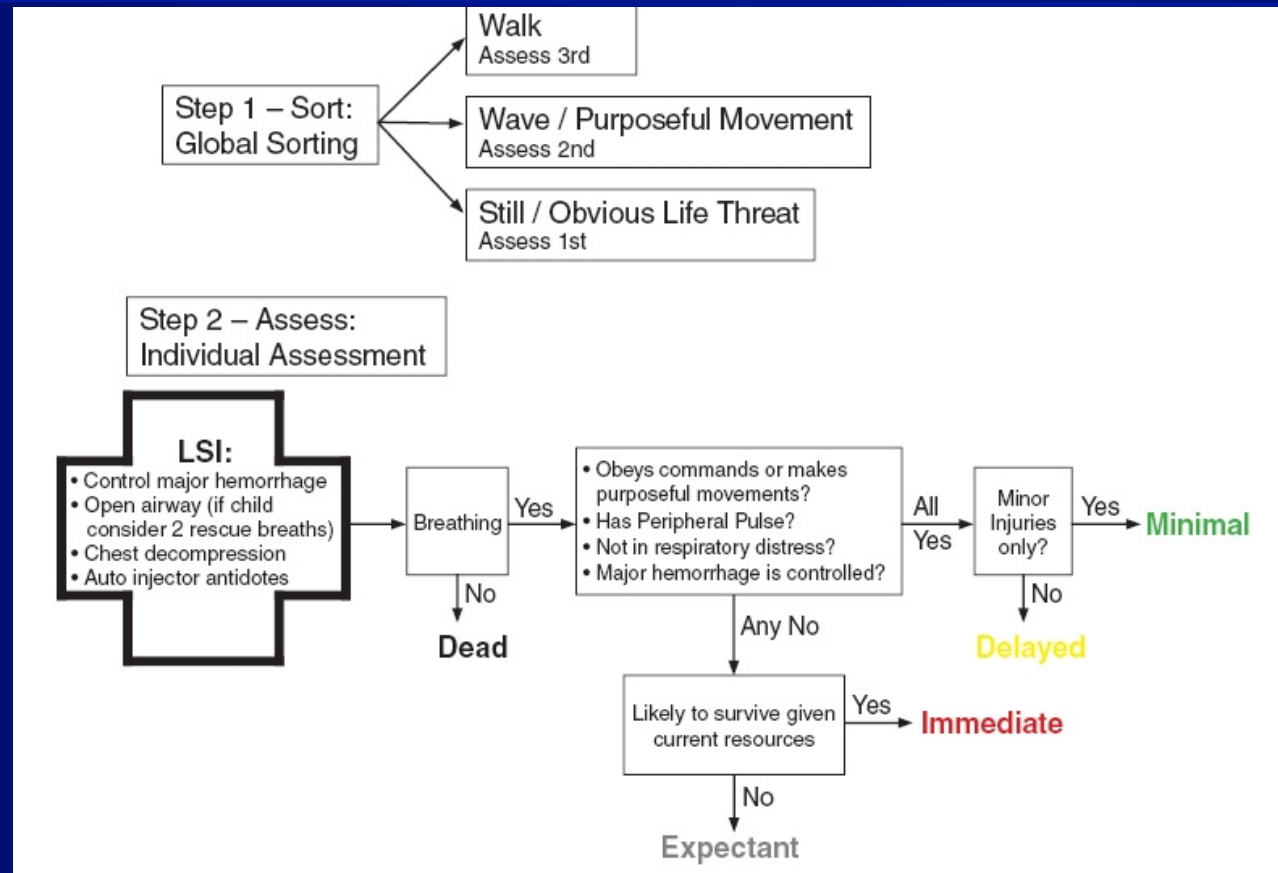


Frykberg E, *J Trauma*. 2002;53(2): 201-212

Real world challenges

- Lack of training for personnel
- Closed vs. open doors
- TM rupture = difficult communication
- Blood donations > requirements
- Equipment issues (e.g., external fixators)
- Casualty tracking

Model uniform core criteria for mass casualty triage



Lerner, et.al., *Disaster Med and Public Health Prep.* 2008 2: S25-34

Summary

- Terrorists prefer conventional bombs
- Explosions combine four main blast mechanisms of injury
- Multidimensional & complex injuries
- System challenges require innovative and multidisciplinary approach

<http://www.bt.cdc.gov/masscasualties/blastinjuryfacts.asp>