

# **Bombings: Injury Patterns and Care**

**Clinician Outreach and  
Community Activity (COCA)  
Conference Call  
August 3, 2010**



# TODAY'S PRESENTER



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Consultant  
National Center for Injury Prevention and  
Control - CDC

# Objectives

**At the conclusion of this hour, each participant should be able to:**

- 1. Discuss current global context of bombings**
- 2. Describe the four categories of blast injury**
- 3. Discuss the management and care of blast casualties**

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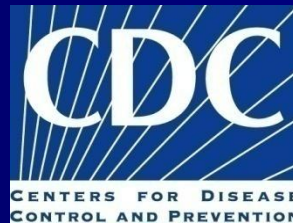
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# Bombings: Injury Patterns & Care



**Version 2.0**

# TIIDE partners

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

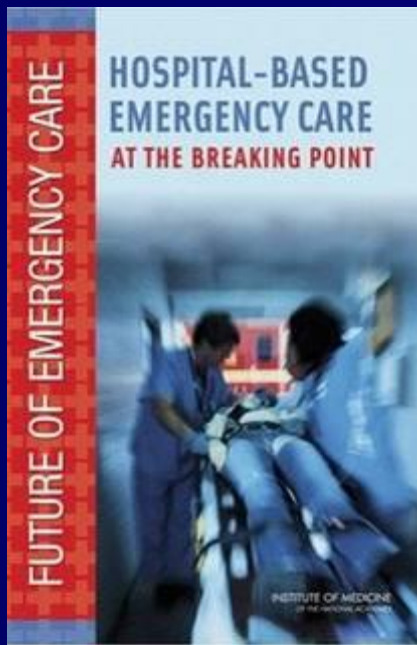
# TIIDE partners

- 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



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

# Institute of Medicine, 2006



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

Used with permission of the Institute of Medicine of the National Academies

# 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<sup>a</sup>

Variable	Terrorist Bombings (%)	Other Trauma (%)
ISS >15	28.7	10.0
GCS <6	9.5	2.9
Admission BP <90 mmHg	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

<sup>a</sup>Adapted 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**

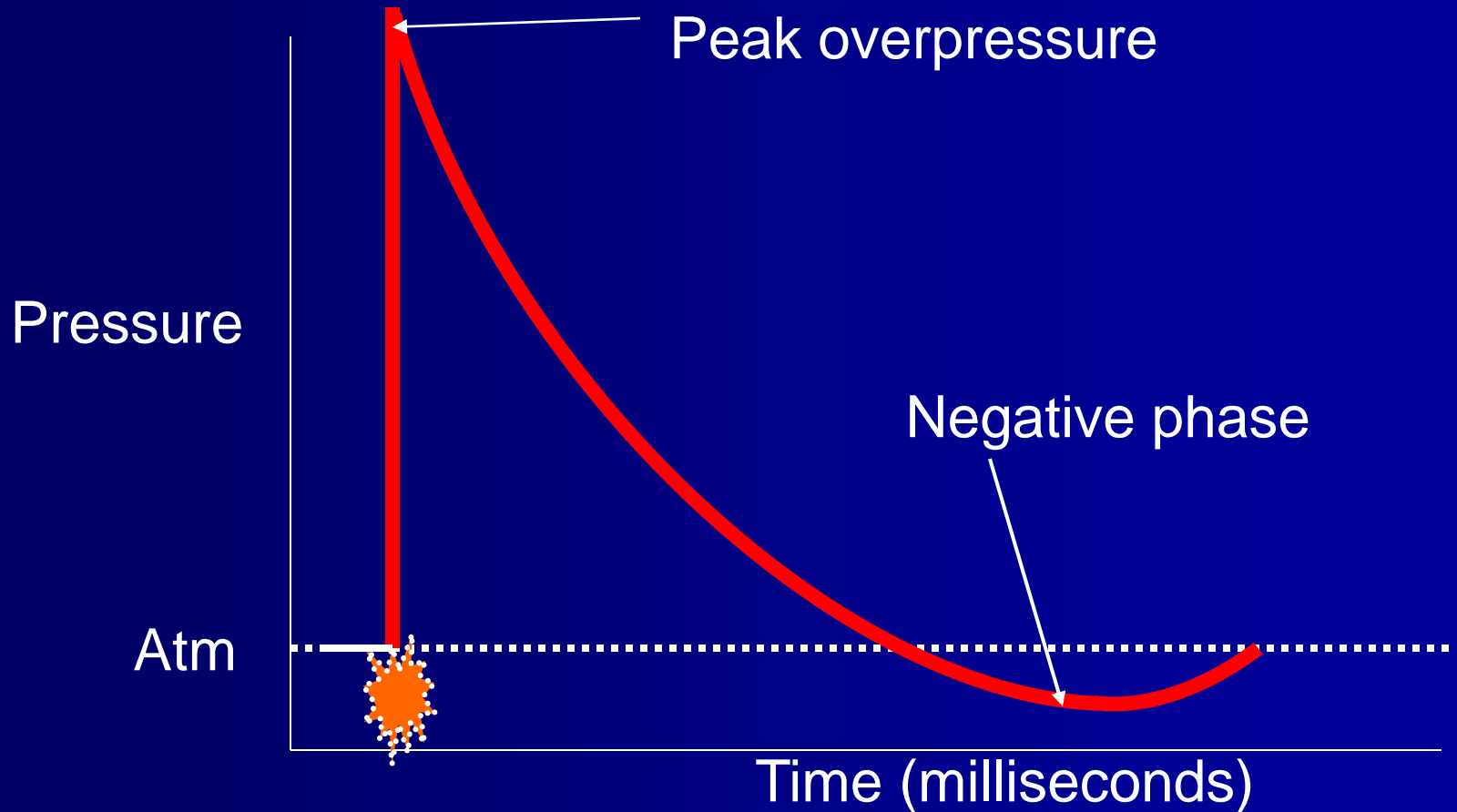
# Explosives

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

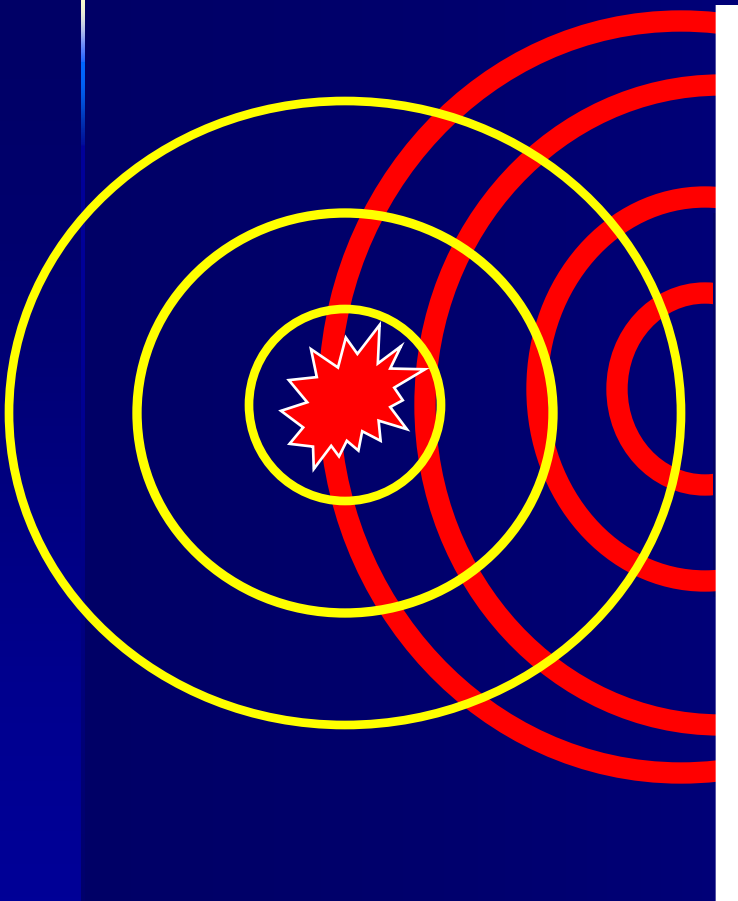
# High energy explosions

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

# Ideal blast waveform

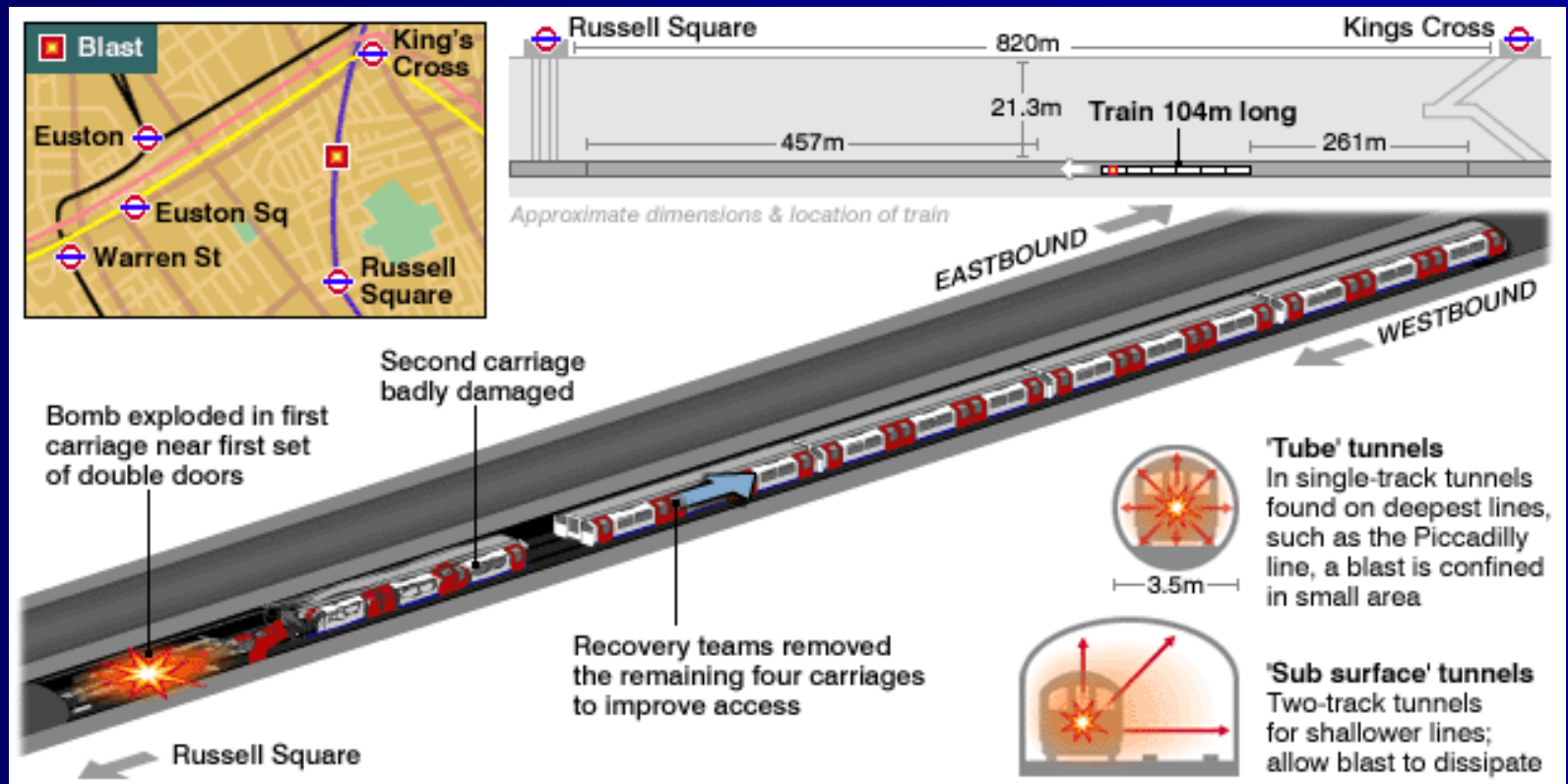


# Waves & surfaces



- 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](http://DeshGujarat.Com)/Japan K Pathak

# Quaternary blast injuries

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



[DeshGujarat.Com](http://DeshGujarat.Com)/Japan K Pathak

# Quinary blast injury (?)

- Contamination
  - Additives
  - Industrial

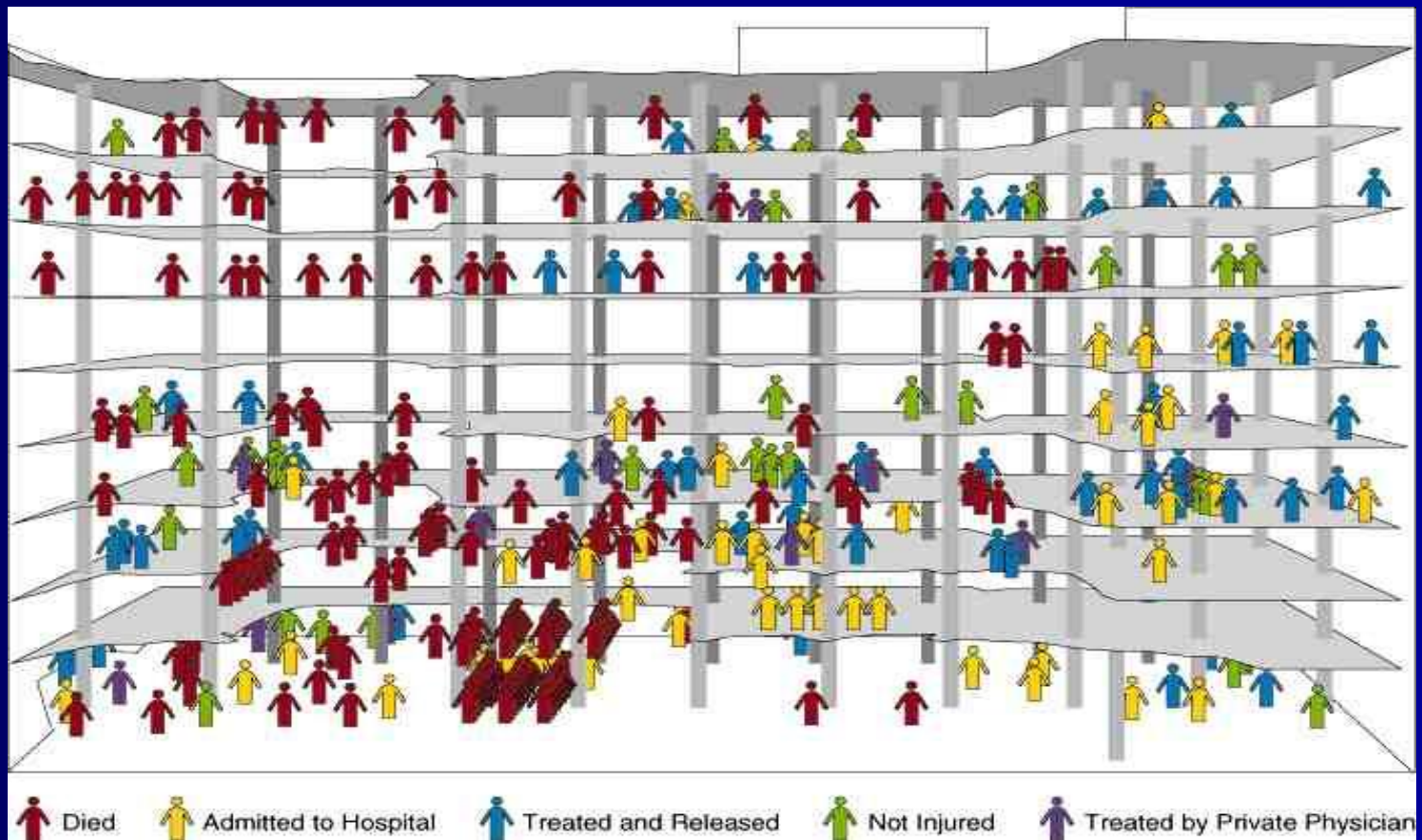
<https://blastinjuryresearch.amedd.army.mil/about.cfm>



# 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

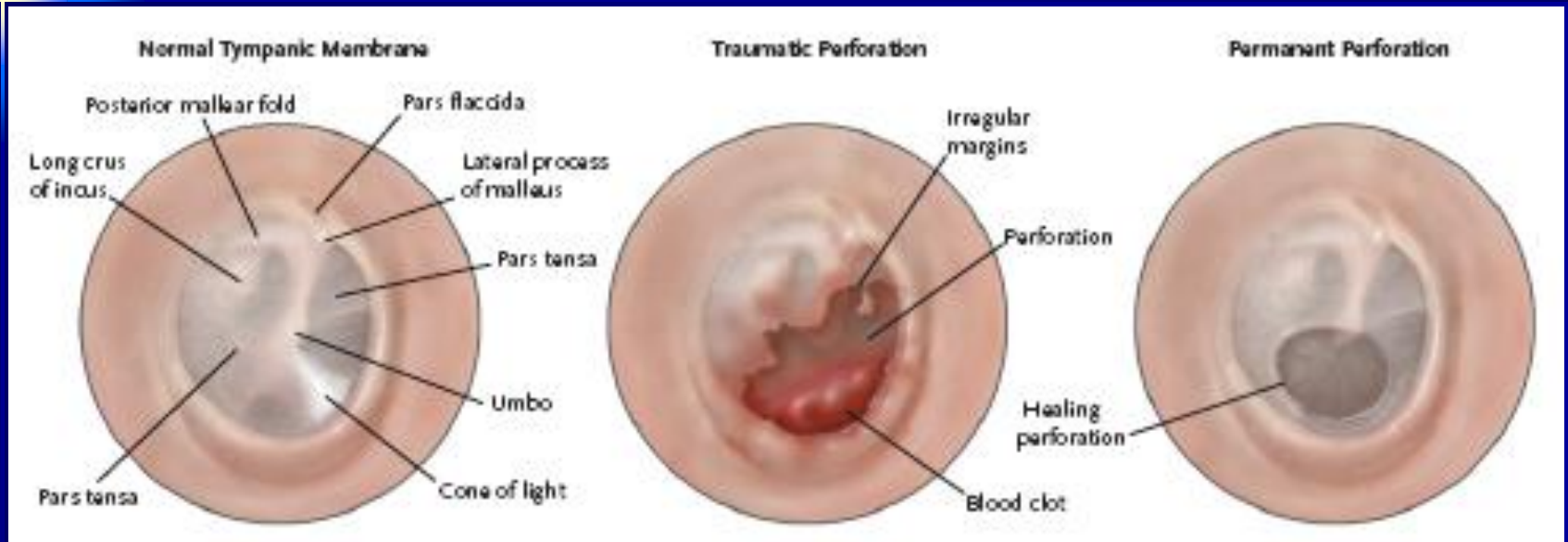
- External ear amputation = death
- Middle ear
  - Ruptured tympanic membrane most common blast injury
- Inner ear
  - Stunned receptors & sensorineural hearing loss

# Tympanic membrane rupture

- $\geq 5$  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](http://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
- 2<sup>nd</sup>/3<sup>rd</sup> 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](http://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](http://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](http://www.emergency.cdc.gov/masscasualties/blastinjury-bombings-mentalhealth.asp).



# HBV, HCV, & HIV postexposure?

<b>Risk category</b>	<b>HBV*</b>	<b>HCV†</b>	<b>HIV§</b>
Category 1. Penetrating injuries or nonintact skin exposures <sup>‡</sup>	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 <sup>††</sup>	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](http://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



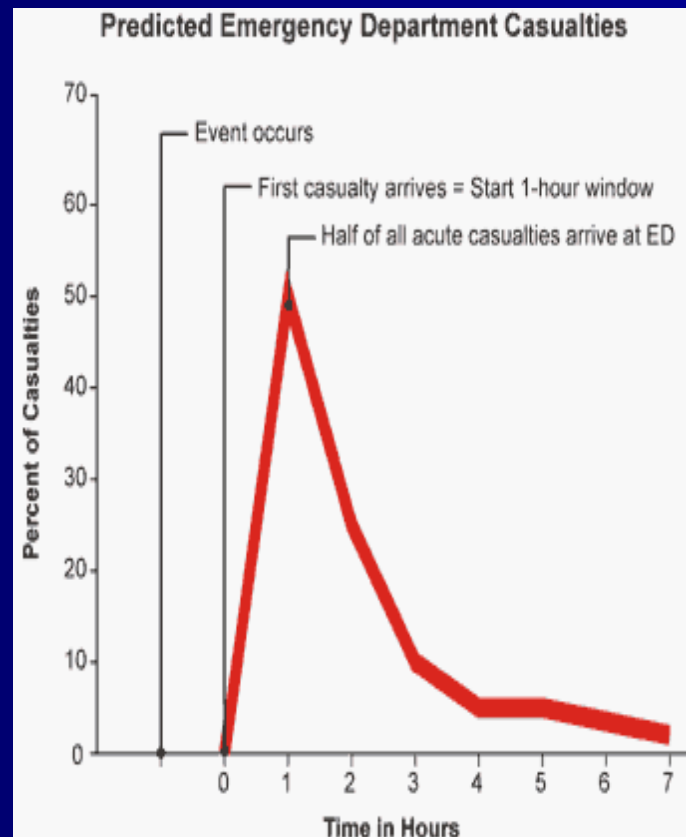
# Are there patterns?

**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)

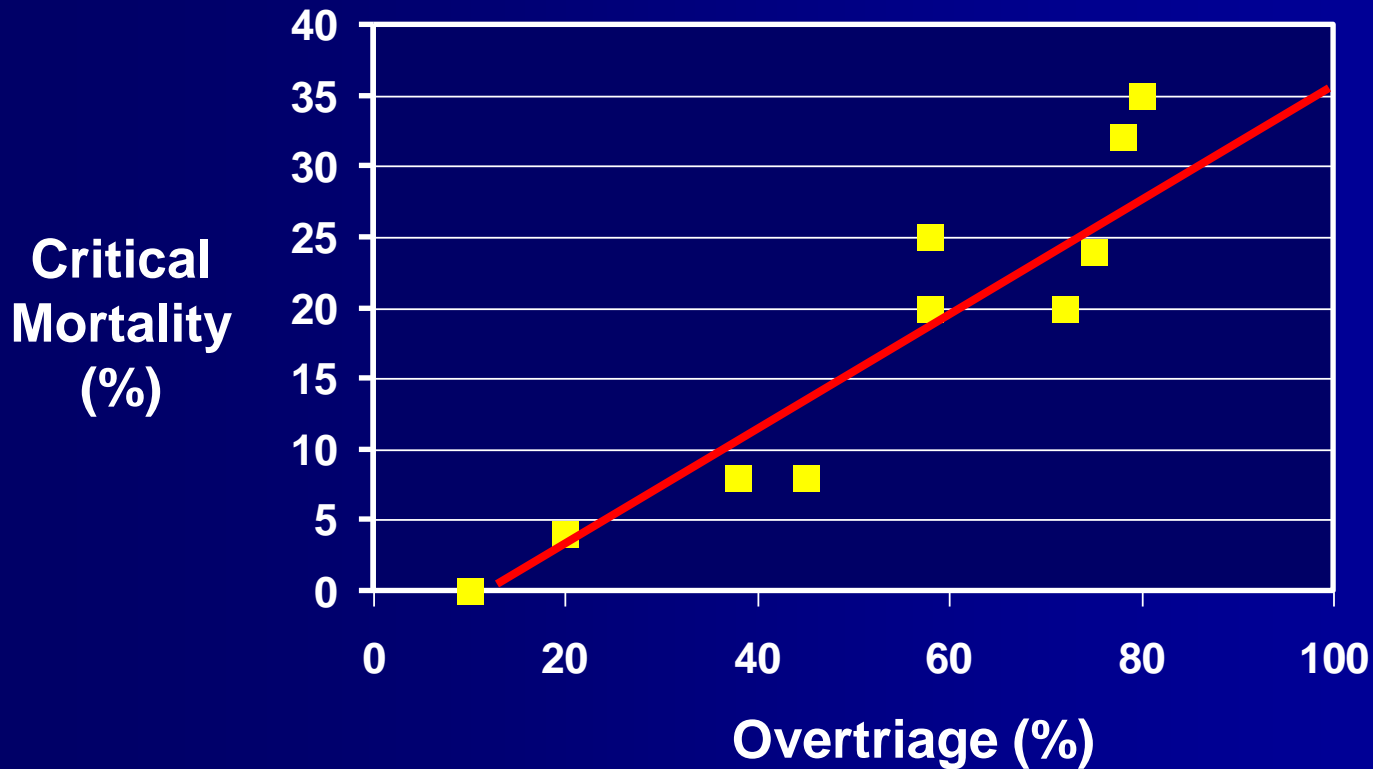
This table was published in "Explosion and Blast Related Injuries", Elsayed & Atkins, 2008, ©Elsevier

# Simplified casualty predictor



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

# Overtriage & critical mortality

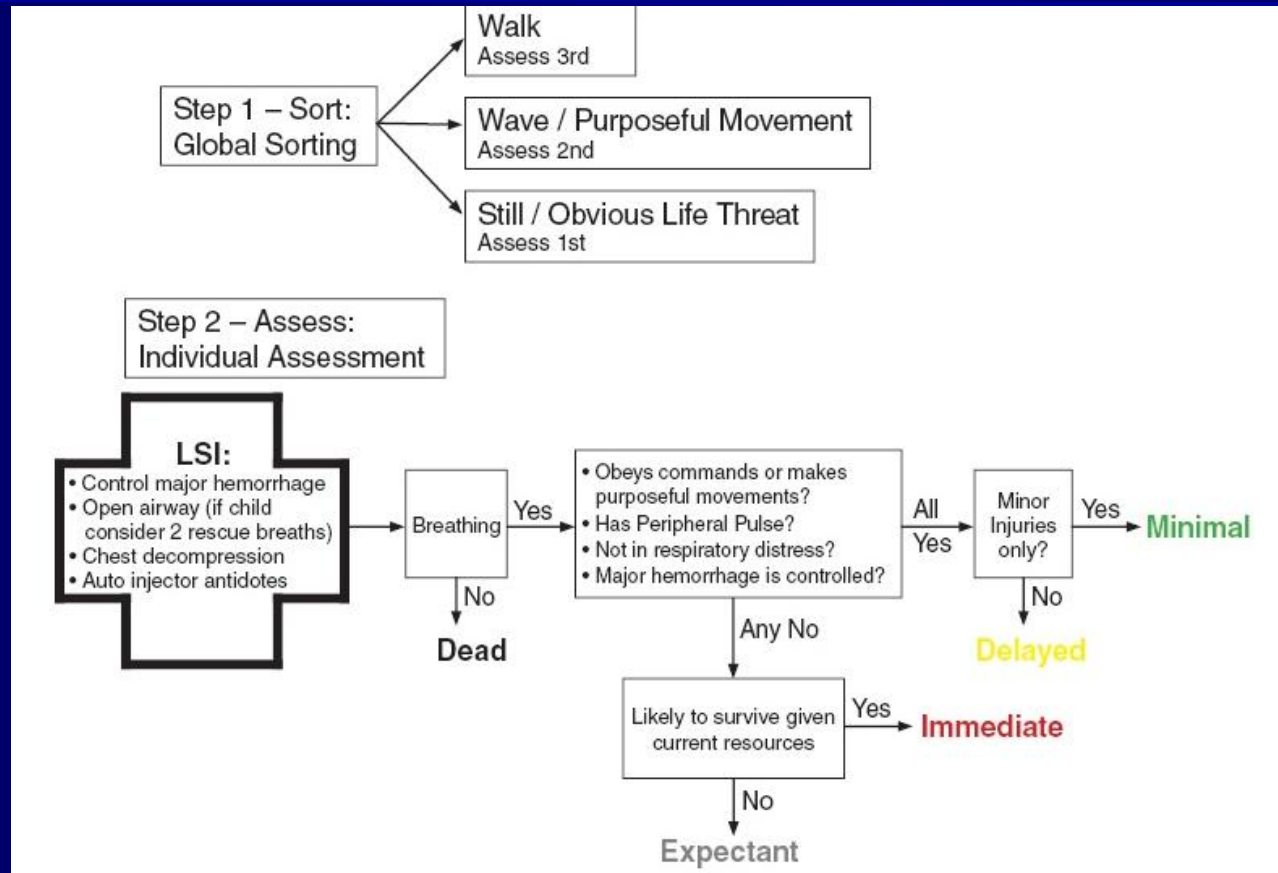


Frykberg E, *J Trauma*. 2002;53(2): 201-212

# 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>

# Continuing Education Credit/Contact Hours for COCA Conference Calls

Continuing Education guidelines require that the attendance of all who participate in COCA Conference Calls be properly documented. All Continuing Education credits/contact hours (CME, CNE, CEU, CECH, and ACPE) for COCA Conference Calls are issued online through the CDC Training & Continuing Education Online system <http://www2a.cdc.gov/TCEOnline/>.

Those who participate in the COCA Conference Calls and who wish to receive CE credit/contact hours and will complete the online evaluation by **Sep 10 2010** will use the course code **EC1648**. Those who wish to receive CE credits/contact hours and will complete the online evaluation between **Sep 11, 2010** and **Sep 10, 2011** will use course code **WD1648**. CE certificates can be printed immediately upon completion of your online evaluation. A cumulative transcript of all CDC/ATSDR CE's obtained through the CDC Training & Continuing Education Online System will be maintained for each user.

# Thank you for joining the call - Please email us questions at [coca@cdc.gov](mailto:coca@cdc.gov)

The screenshot shows a Windows Internet Explorer browser window displaying the CDC Clinician Outreach and Communication Activity (COCA) website. The address bar shows the URL <http://emergency.cdc.gov/coca/callinfo.asp>. The page title is "CDC Clinician Outreach and Communication Activity (COCA) | Conference Calls".

The left sidebar contains a navigation menu with the following items:

- Emergency Preparedness & Response
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- Clinician Resources
- Conference Call Info, Summaries, & Slide Sets
- Past Updates from the Registry
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- What You Can Do
- What's New

The main content area features the following sections:

- Conference Calls**: A breadcrumb trail reads "EPR > Preparedness for All Hazards > Clinician Resources". The text states: "COCA's goal is to help you provide the best health care possible. We offer conference calls, podcasts and other tools for potential emergencies and emerging health threats. Here you will find our most recent COCA call information and archived call materials, as well as information on continuing education credit." Below this, it says: "If there's a topic you'd like us to cover, let us know at [coca@cdc.gov](mailto:coca@cdc.gov)."
- Upcoming Conference Call**:
  - Title:** Bombings: Injury Patterns and Care **CE**
  - Date:** Tuesday, August 3, 2010
  - Time:** 2:00 PM – 3:00 PM (Eastern Time)
  - Overview:** Could You Treat 270 patients in two and a half hours? On March 11, 2004, 10 terrorist explosions occurred almost simultaneously on commuter trains in Madrid killing 177 people instantly and injuring more than 2,000. That day, 966 patients were taken to 15 public community hospitals. More than 270 patients arrived at just one hospital in two and a half hours. So you may be thinking... something like this won't happen at my hospital or on my shift. Unfortunately, the fact is, you must be ready to confront an event like the Madrid bombings. Current trends in global terrorism demand that clinicians are prepared for treating injuries caused by explosions no matter our location or the size of our hospital. During this conference call, a CDC SME will provide current, relevant clinical information regarding blast related injuries from terrorism and discuss current global context of bombings, categories of blast injury and appropriate management and care of blast casualties.
  - Speaker:** Scott Sasser, MD, FACEP

The right sidebar contains utility links and contact information:

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