

Clinical Manifestation of Blast Injuries  
ADVANCED EXPLOSIONS & BLAST INJURIES

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Outline

- Types of injuries seen
- Injury characterization
- Specific Injuries
  - Primary
  - Secondary
  - Tertiary
  - Quaternary
  - Quinary

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Madrid Bombing - Injuries

- Rupture of the tympanic membranes occurred in 99 of 243 victims
- Chest injuries in 97/243 victims
- Shrapnel wounds in 89/243
- Fracture in 44
- Burns in 45
- Eye injuries in 41
- Abdominal injuries in 12
- Traumatic amputations in 5

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## Boston Marathon Bombing-April 15, 2013

- 3 deaths prior to reaching the hospital
- 264 injuries
- More than 20 with critical injuries
- Amputations, soft tissue injuries
- TM rupture




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## Trauma Activations at Mass General Hospital

Table 1  
Patient demographics

Characteristic	Mean victims (n = 10)
Age (yr) - mean ± SD	29.1 ± 15.4
Sex	
Male, n (%)	6 (60%)
Female, n (%)	4 (40%)
RIS - mean ± SD	13.6 ± 9.0
LOS in arrival - mean ± SD	14.4 ± 6.8
IKU on arrival (L) - mean ± SD	25.5 ± 8.0
IKU on arrival (R) - mean ± SD	12.0 ± 2.8
Sys BP on arrival - mean ± SD	114.8 ± 24.2
HR on arrival - mean ± SD	166.7 ± 25.7
Sys BP before surgery - mean ± SD	121.2 ± 25.9
HR before surgery - mean ± SD	86.0 ± 24.0
Blood loss (ml) - median (Q1-Q3)	250.0 (200-400)
PRBC total - mean ± SD	6.1 ± 7.6
FFI - mean - mean ± SD	4.5 ± 8.0
Fluorine total - mean ± SD	4.7 ± 5.2
Surgical services	
Trauma and emergency surgery, n (%)	8 (80%)
Orthopedic surgery, n (%)	2 (20%)
Time from admission to first surgery (min) - median (Q1-Q3)	54.0 (40.0-102.0)

SpB indicates systolic blood pressure; FIBI, packed red blood cells; RFP, Fresh Frozen Plasma.

Table 2  
Description of outcomes

Characteristic	Mean victims (n = 10)
Number of LOS per patient - median (Q1-Q3)	4.0 (1.0-5.0)
LOS	
Amputations, n (%)	5 (50%)
Blood transfusions, n (%)	5 (50%)
Intubation, n (%)	6 (60%)
Vasopressors, n (%)	7 (70%)
CR, n (%)	1 (10%)
Surgeries, n (%)	10 (100%)
Total number of LOS	34 (340%)
IKU LOS - median (Q1-Q3)	13.5 (6.0-18.0)
KU LOS - median (Q1-Q3)	10 (5.0-4.0)
Mortality, n (%)	0 (0%)

LOS indicates hospital length of stay; KU LOS, intensive care unit length of stay.

Peck MJ, et al. Real-time sample entropy predicts life-saving interventions after the Boston Marathon bombing. J Trauma. 2013;114(2):113.

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**Tertiary Blast Injury**  
(Injuries due to impact with another object)



**Secondary Blast Injury**  
(Injuries due to missiles being propelled by blast force)

**Primary Blast Injury**  
(Injuries due to the blast wave itself)

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### Primary Blast Injuries

- Affect air-filled organs or air-fluid interfaces
- Rupture of tympanic membranes, pulmonary injury, air embolization and rupture of hollow viscera are the most common patterns

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### Tympanic Membrane Rupture

- Occurs at the lowest pressure (5 psi)
- May be bilateral
- May be the earliest sign to look for
  - Deafness, tinnitus and vertigo
- If more severe, may cause dislocation of the oval, round window or the ossicles
  - Permanent hearing loss
- Other organs need higher pressures (56-76 psi) so if the TM is intact, they are unlikely

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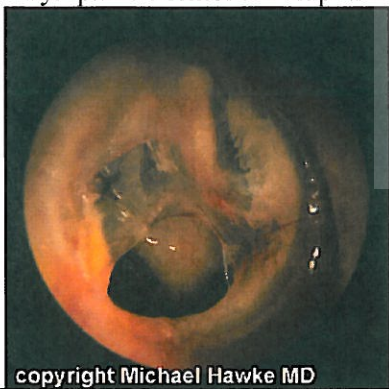
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### Tympanic Membrane Rupture



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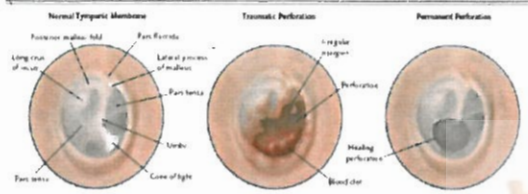
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## Normal and Perforated Right Tympanic Membranes



The drawing of a traumatic perforation shows an irregular margin or rim with blood or a blood clot, and the drawing of a permanent central perforation shows a tympanocele

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## Pulmonary Injuries

- Second most common primary blast injury
- Hemorrhage
  - Pulmonary contusion (appearing as a bilateral "butterfly" pattern on chest radiographs)
  - Pneumothorax
  - Hemothorax
  - Pneumomediastinum
  - Subcutaneous emphysema

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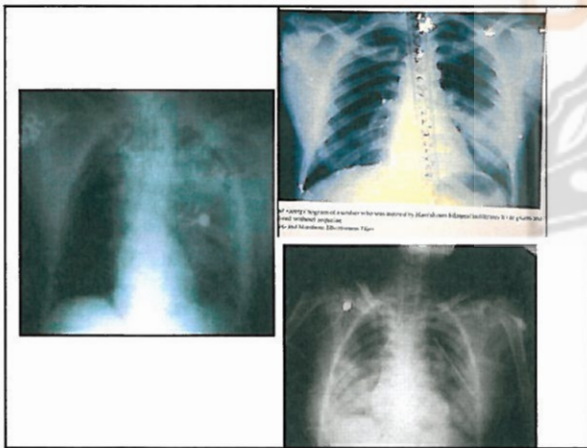
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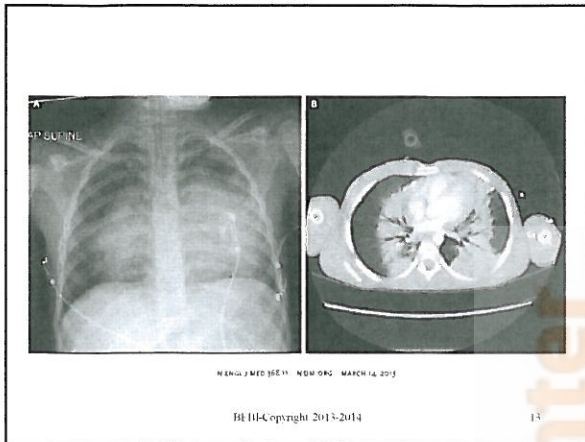
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### Pulmonary Injuries

- Onset of symptoms is commonly within minutes
  - Controversial

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### Body Armor

- Protects from secondary blast injuries
- Does not protect from primary blast injury

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## Kevlar Helmet



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## TM Perforation - Pulmonary Injury

- Among 17 critically ill victims with pulmonary injuries from the blast:
  - 13 had ruptured tympanic membranes and 4 did not
- Rupture of tympanic membranes occurred in 18 of 27 critically injured victims
  - 17 of these were bilateral

*Data from Madrid*

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## Screening

- 647 survivors of explosions on buses used immediate radiography of the chest to screen for pulmonary injuries from the blasts
- Primary injuries, in some form, were found in 193 persons:
  - 142 had isolated perforation of the eardrum

*Data from Israel*

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## Screening

- 51 had other forms of primary blast injuries:
  - 18 with isolated pulmonary injuries
  - 31 with combined otic and pulmonary injuries
  - Two with intestinal injuries

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## Visceral Injury

- Visceral injury is third most common primary blast injury
- Rupture of the colon and, less frequently, the small intestine may occur as an immediate result of a blast
- Mesenteric ischemia or infarct can cause delayed rupture of the large or the small intestine; these injuries are difficult to detect initially

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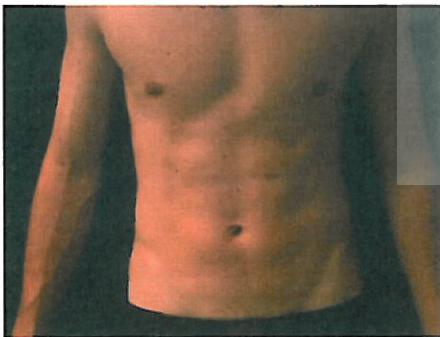
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### Visceral Injuries



- The ileocecal area is the most vulnerable
  - Accumulates gas
- Observed findings
  - Hemorrhages
  - Edema
  - Perforations
  - Lacerations

Fig. 4. Gross view of a patient with a blunt abdominal injury. The abdomen is distended and there is a large amount of bruising and discoloration of the skin. The patient is in pain and has a tachycardic and hypotensive vital signs.

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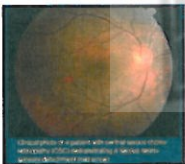
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### Other Injuries

- Serous retinitis
- Concussion
- Air embolism may be seen and can present as stroke, MI, acute abdomen, blindness, deafness, spinal cord injury, or claudication



Ultrasound image of a patient with a retinal detachment. The retina is seen as a bright, echogenic line that is detached from the underlying choroid. The vitreous body is seen as a dark, anechoic area.

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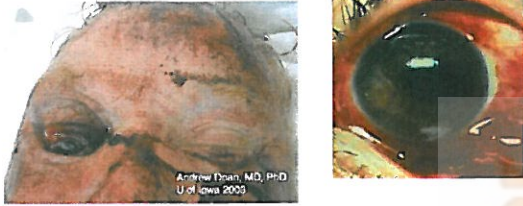
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## Ruptured Globes



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## Secondary Injuries

- Penetrating injuries from:
  - Primary fragments (fragments that are part of the weapon)
  - Secondary fragments (those that result from the explosion)

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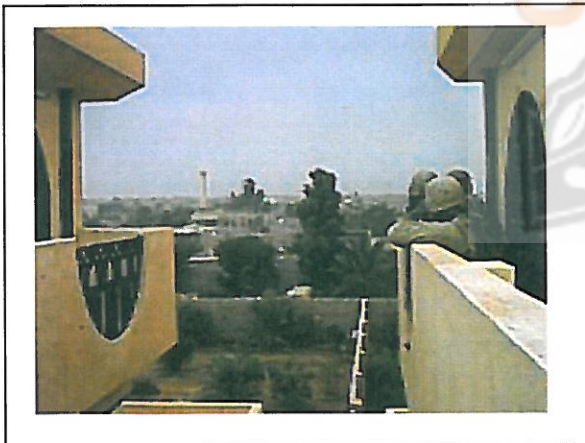
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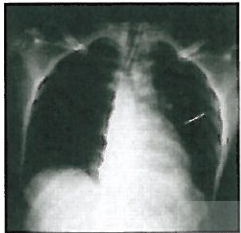
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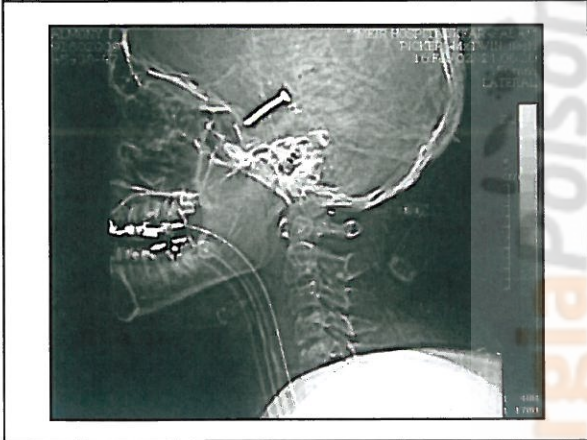
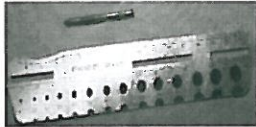
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Protopopov and Edwards Med. Bull. 2011; 6:24  
Figure 1—Photograph of the patient's abdomen showing a small suprapubic entry wound



Protopopov and Edwards Med. Bull. 2011; 6:24  
Figure 2—Chest radiograph showing a nail embedded in the patient's left lung



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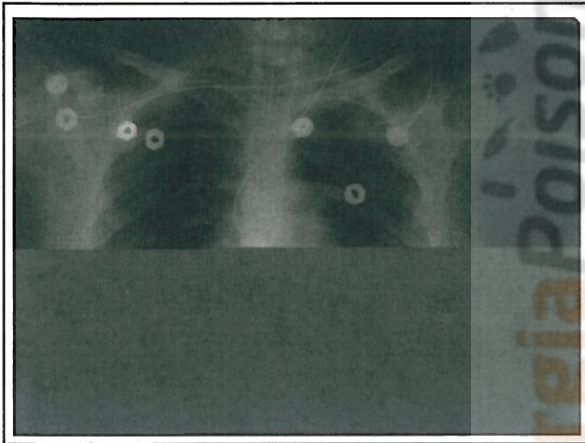
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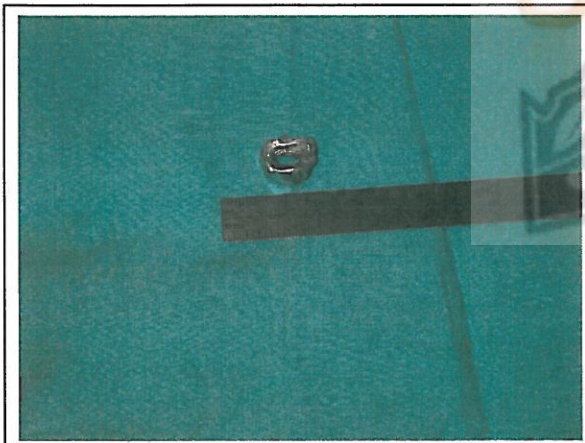
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Georgia Poison Center  
TRAINING

## Tertiary Injuries

- Caused by trauma from falling objects or from bodies being thrown against other objects
  - Blunt and penetrating injuries
  - Crush syndrome and secondary rhabdomyolysis
  - Open or closed head injuries



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## Crush Syndrome

- Rhabdomyolysis:
- Myoglobinuric renal failure
- Hyperkalemia



An Electrocardiographic Sine Wave in Hyperkalemia



Source: NEJM and Well.com/mem

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## Pelvic Fractures



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## Crush Syndrome-Earthquakes

Table 1. Statistics Related to Major Earthquakes in the Past 18 Years.<sup>27</sup>

Location and Year	Death	Crush Syndrome <i>overall number of crush victims</i>	Dialysis
Sp. Isl., Armenia, 1988 <sup>21,22</sup>	25,000	600	225-385
Northern Iran, 1990 <sup>23</sup>	>40,000	?	156
Kobe, Japan, 1995 <sup>19,20</sup>	5,000	372	123
Marmara region, Turkey, 1999 <sup>21</sup>	>17,000	639	477
Chi-Chi, Taiwan, 1999 <sup>22</sup>	2,405	52	32
Gujarat, India, 2001 <sup>21</sup>	20,023	35	33
Boumerdes, Algeria, 2003 <sup>24</sup>	2,766	20 <sup>2</sup>	157
Bam, Iran, 2003 <sup>25</sup>	26,000	124	96
Kashmir, Pakistan, 2005 <sup>26</sup>	>80,000	138	65
Total	>217,000	>1900	>1200

## Rhabdomyolysis

- Secondary complication of crush syndrome
- Myoglobinuria and CK elevation

## Quaternary Injuries

- Burns (chemical or thermal)
- Toxic inhalation of carbon monoxide or hydrogen cyanide gas
- Exposure to radiation: ARS and Internal Contamination
- Inhalation of dust containing coal or asbestos
- Exacerbation of chronic illnesses

### Exacerbation of Chronic Illnesses

- Asthma and COPD
- Diabetes Mellitus
- Hypertension
- Coronary artery disease
- Peptic ulcer disease
- Alcohol and substance abuse
- Mental health

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### Quinary Blast Injuries

- SIRS manifestations
  - Fever
  - Tachycardia
  - Hypotension
- No infectious source recognized
- BAL reveals eosinophilia
- Management supportive +/- steroids

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### Any Questions or Comments?

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