

History

- Halifax, Nova Scotia December 6, 1917
 - Belgian ship Imo collides with French munitions ship Mont Blanc
 - 35 tons of benzene ignite on top deck of the Mont Blanc
 - 15 minutes later the fire ignites 2300 tons of picric acid, 10 tons of gun cotton, 300 rounds of ammunition and 200 tons of TNT
 - 2.5 km of city leveled, 150 tidal wave, 2000 dead, 9000 injured, 20,000 homeless (in a city of 50,000), entire fire department lost

April 16, 1947, Texas City, Texas

- The ship Grand Camp catches fire
- 20 minutes later cargo of ammonium nitrate fertilizer explodes
- A second more powerful blast shortly later followed by a 150 foot tidal wave
- 600 deaths in a city of 16,000—loss of entire fire department

1970's-80's Ireland

- 1532 bombing victims, 9 hospital deaths*
 - 10 chest and abdominal injuries-5 deaths
 - 16 major limb amputations, 4 deaths
 - 50 superficial burns-none required skin grafts
- 828 British servicemen killed or injured in bombings 1979-84**
 - 216 deaths (26%). Most died at the scene

*Hadden WA, Rutherford WH, Merritt JD The injuries of terrorist bombing: a study of 1532 cases Br J Surg 1978;65:525-31.

**Mellor SG, Cooper CJ. Analysis of 828 British servicemen killed or injured by explosion in Northern Ireland 1970-84: the Hostile Action Casualty System Br J Surg 1989;76:1006-10.

Sha'arei Zedek Medical Center 1975-79

- 24 terrorist explosions – 511 casualties
 - 340 casualties a SZMC
 - 26 (7.6%) DOA or died in ER
 - 272 required admission
 - 3 (1.1%) died in hospital
 - 13 open air explosions
 - 6 indoor explosions
 - 5 bus explosions
 - Overall mortality 8.5%

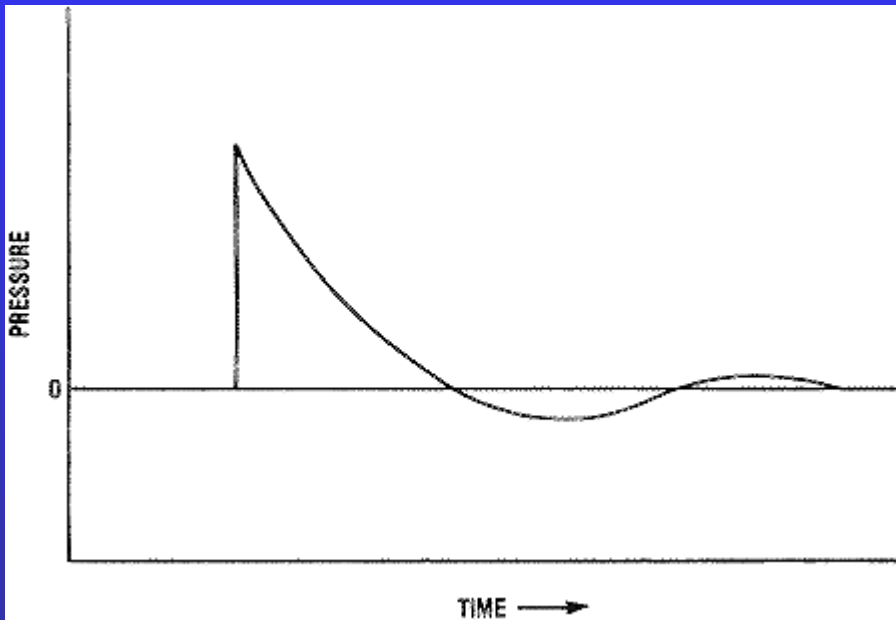
Adler J, Golan E, Golan J et al. Terrorist Bombing Experience during 1975-79: Casualties admitted to the Shaare Zedek Medical Center. *Isr J Med Sci* 1983;19: 189-93

Classification of Explosives

- High Order Explosives
 - TNT
 - C-4
 - Semtex
 - Nitroglycerin
 - Dynamite
 - Ammonium Nitrate Fuel Oil
- Low Order Explosives
 - Pipe Bombs
 - Gunpowder
 - Petroleum based bombs (Molotov Cocktails)
 - Aircraft used as guided missiles (Sept. 11)

Physics of Blast Wave

Pressure Wave in Air



- Pressure Wave close to explosion moves at supersonic speed
- Speed of wave progression in water greater than in air and force maintained with distance

Physics of Blast Wave

- If pressure wave in close apposition to a solid barrier, the pressure wave reflected off the solid barrier may be many times greater than the initial pressure wave
- A low grade pressure wave in an out of doors explosion maybe a lethal pressure wave in a closed space

Category

Potential Injuries

Primary	Lung Tympanic Membrane Intestine Ruptured Globe Cerebral Concussion
Secondary	Penetrating Trauma High risk of penetrating eye injury
Tertiary	Closed and Open head Injury Fractures Traumatic Amputations
Quaternary	Burns Crush Injuries Bloodborne Infections Smoke/dust inhalation Exposure to Nonconventional Weapons

Terrorist Bombing Victims at SZMC

Jan 1995-Jan 2004

Injury	N (%)	Closed Space N(%)	Open Space N(%)
Blast Lung	23 (50)	18 (72)	5 (24)
Burns	14(30)	10 (40)	4 (19)
Abd solid organ	7 (15)	2 (9)	5 (24)
Penetrating GI Injury	3 (6.5)	1 (4)	2 (9.5)
Intest Blast Injury	1 (2)	1 (4)	0
Vasc Injury	5 (11)	1 (4)	4 (19)
Rupt Tympan Membrane	26 (56)	19 (76)	4 (19)

BLAST LUNG INJURY FOLLOWING TERRORIST BOMB ATTACKS

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Introduction



Introduction

06/12/1983

21/08/1995

25/02/1996

03/03/1996

30/07/1997

04/09/1997

06/11/1998

02/11/2000

27/03/2001

27/05/2001

09/08/2001

01/12/2001

27/01/2002

02/03/2002

09/03/2002

17/03/2002

21/03/2002

29/03/2002

01/04/2002

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30/07/2002

31/07/2002

21/11/2002

18/05/2003

11/06/2003

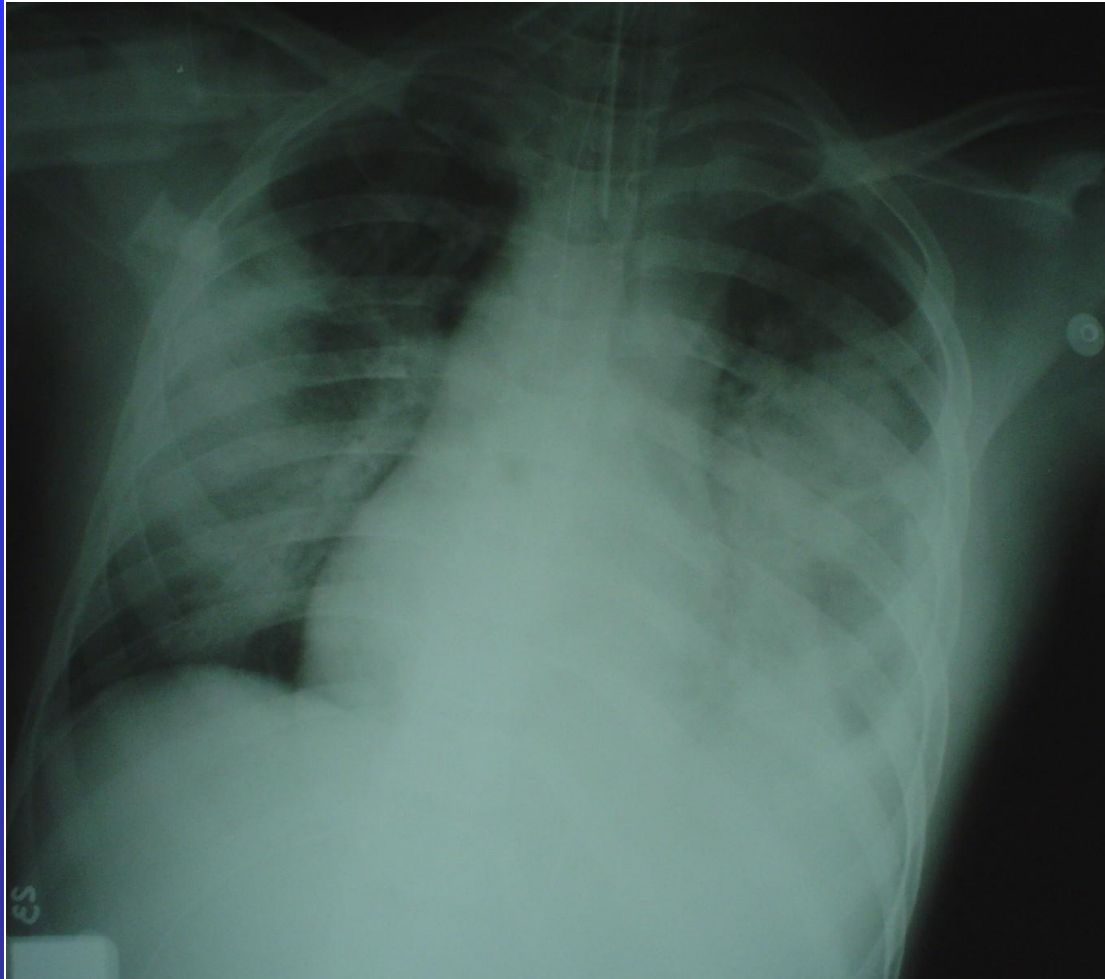
19/08/2003

09/09/2003

21/01/2004

22/02/2004

Blast Lung Injury



Objective

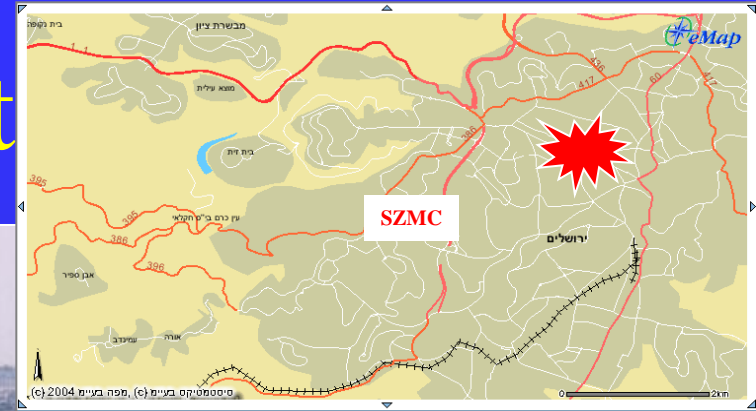
- Review our experience in order to characterize clinical presentation, treatment and outcome.



Setting



Location



Methods

- Retrospective review of patient files
 - Victims of terrorist bomb attacks
 - Blast lung injury
 - ICU admission
 - 12/1983-12/2004.
- Telephone interview.

Results

- 916 ED admissions following 31 TBAs.
- 41 ICU admissions.
- 29 BLI.
- Age: 4-75 years.
- Male:15, Female:14.

24/29 (83%) - Closed Space
Explosions

Clinical presentation

- Hypoxia in all patients
 - dyspnea\ tachypnea
 - cyanosis
 - convulsion, lateralization signs
 - disturbed consciousness, coma
- Hemoptysis \ bloody-frothy tracheal secretions \ bloody NGT aspirate.
- Short deterioration.

Severity of hypoxia - $\text{PaO}_2/\text{FiO}_2$ (Ventilated Patients, n=22)

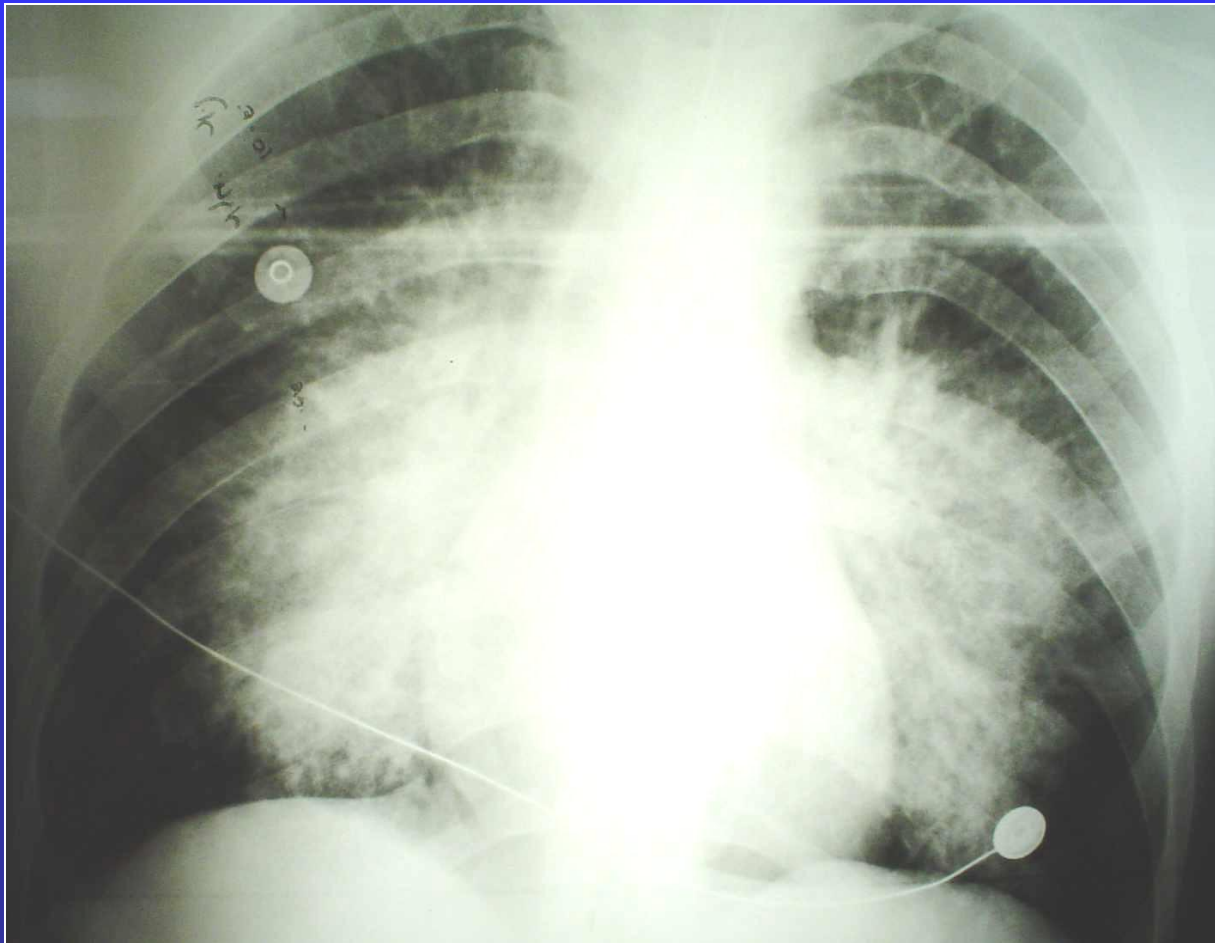
< 60	7 patients
60-100	4 patients
100-200	5 patients
> 200	4 patients
no data	2 patients

Chest X-ray

1. Pulmonary infiltrates:

- Present in all patients.
 - Bilateral - 20
 - unilateral - 9
- May worsen over time and fluid replacement.
- Typical - Butterfly (bat wings) infiltrates.

Butterfly infiltrates



Bat-wing infiltrate



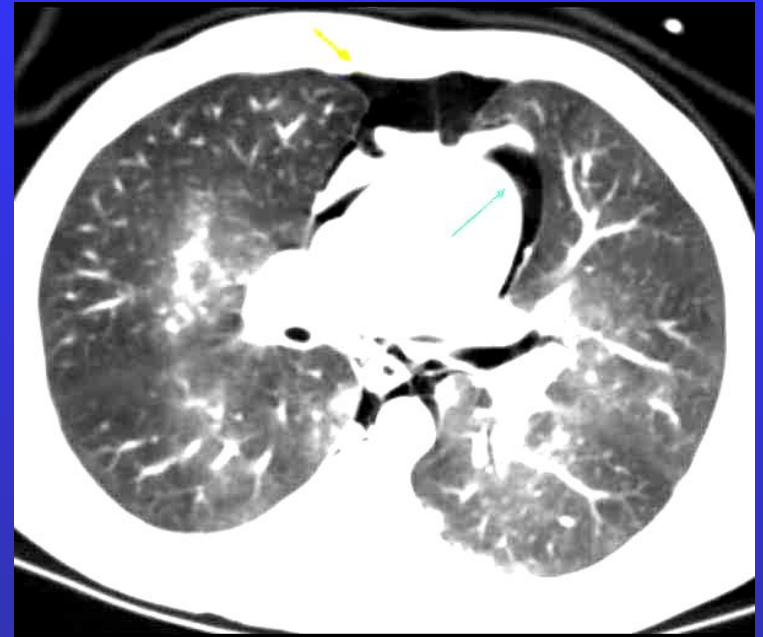
Chest X-ray

2. Pneumothorax:

unilateral	7 patients
bilateral	5 patients

3. Pneumomediastinum:

3 patients



Mechanical Ventilation

- 22/29 (76%) - mechanical ventilation.
- Median length - 4 days (range 1-78).
- Intubation and ventilation:
 - on scene\ in ED 17
 - within 2 hours 4

Mechanical Ventilation - PEEP

<u>Maximal PEEP</u>	<u>n</u>	<u>Aids\ special modes</u>
15	1	NO inhalations
15	1	HFV
14	1	-
12	1	-
10	1	HFV
10	5	-
5	9	-
0	1	-
Missing data	2	-
<i>Total</i>	<i>22</i>	

- Lowest possible PEEP should be used to avoid air emboli.

Fluid replacement

- Keep to a minimum
- Crystalloids \ colloids as needed.

Additional Injuries

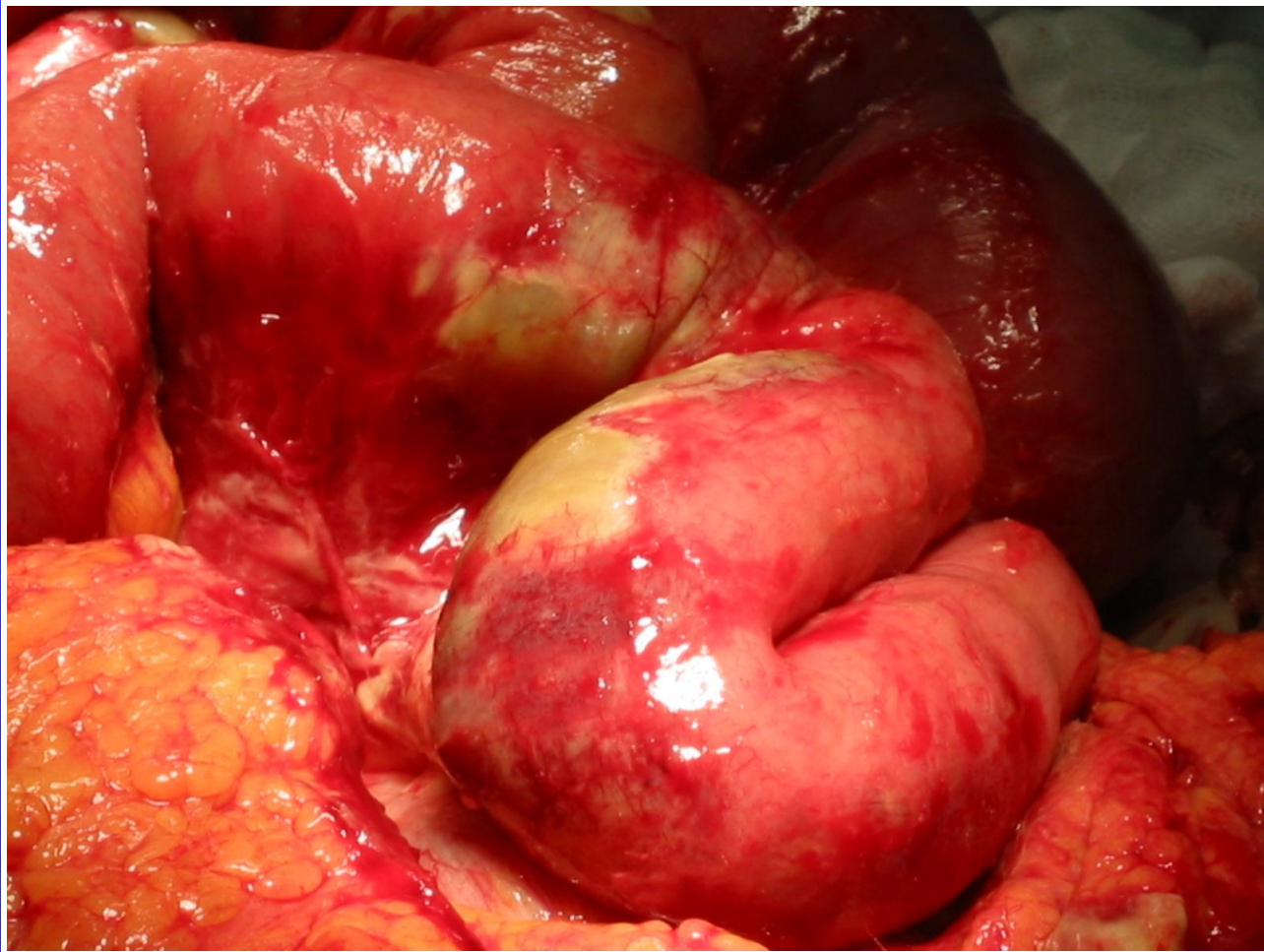
- Primary blast injuries:
 - ruptured tympanic membranes 25 (86%)
 - intestinal blast injury 3 (10%)
- Others:
 - abdominal solid organs 3 (10%)
 - vascular injuries 2 (7%)
 - limb fracture 8 (28%)
 - limb amputation 2 (7%)
 - burns 15 (52%)

Intestinal Blast Injury

- Jerusalem Bus Bombing reported in 1989
- 3 dead at the scene and 55 survivors
- 29 patients hospitalized
- 2 patients with perforated intestine with late presentation (delayed dx vs delayed perforation)

Katz E, Ofek B, Adler J et al. Primary blast injury after a bomb explosion in a Civilian bus. *Ann Surg* 1989;209:484-8

Intestinal Blast Injury



Length of stay

- ICU:
median 6 days (range 1-81).
- Hospital LOS:
median 14 days (range 1-250).

Complications

- 2 patients had suspected air embolus:
 - 1 patient developed VT-VF and acute injury pattern in EKG.
 - 1 patient developed Lt. Hemiparesis which gradually resolved.

Mortality

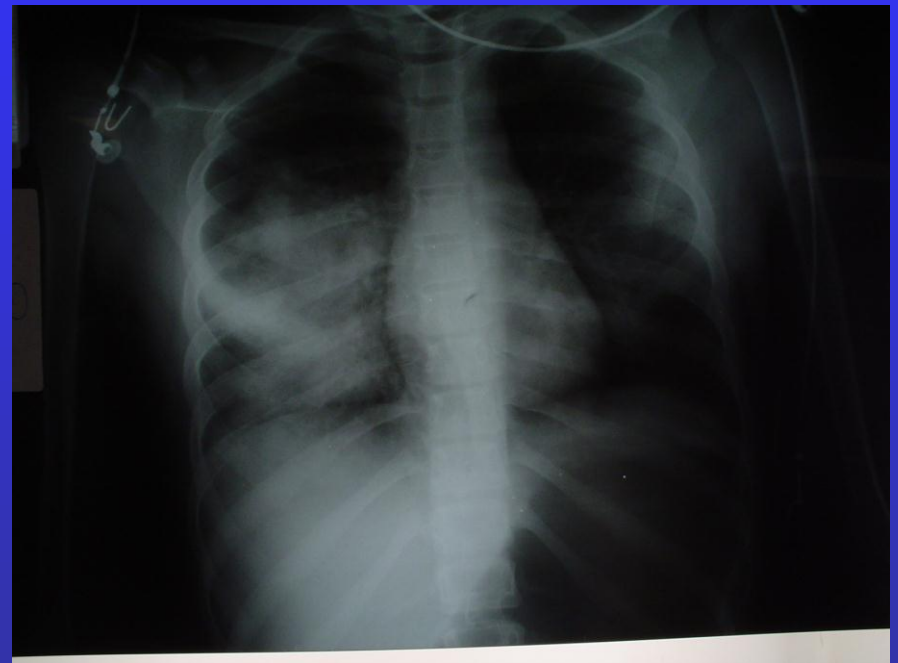
- 1 patient (3.4%) died of sepsis and MOF.

Long term follow-up

- 21/28 survivors responded.
- Follow up: 6 mo - 21 y (median 3y).
- 16 (76%) - no respiratory sequelae.
- 3 (14%) patients - use inhalers
- 1 (5%) patient - respiratory symptoms
- 1 (5%) patient - abnormal PFT

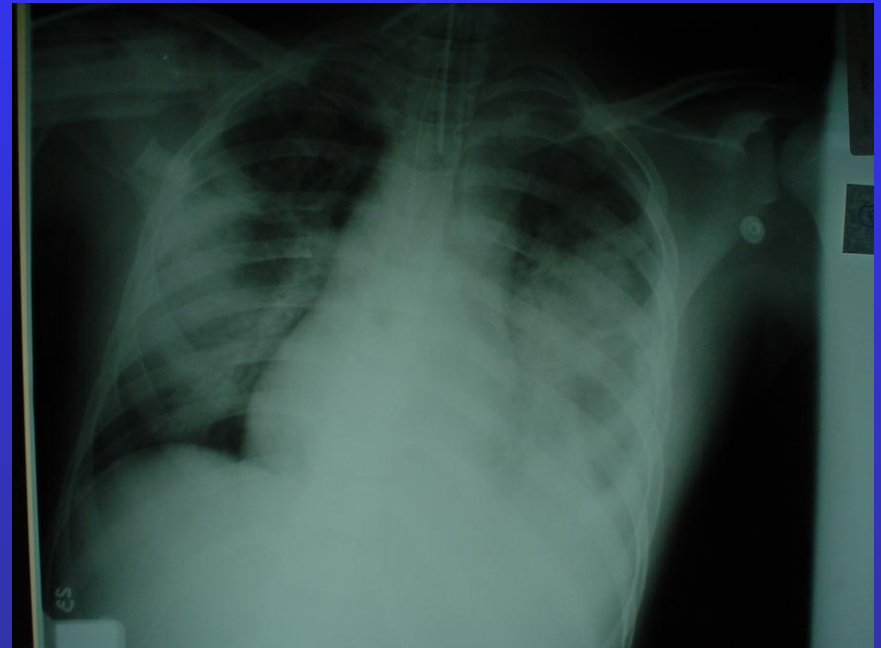
Case 1 Primary Blast Injury

- 12 yo girl involved in bus bombing Jan 23, 2004
- Admitted with SOB but hemodynamically stable
- CT scan ordered 40 minutes after arrival
- Intubated in CT Scan
- Fresh blood suctioned from ET tube



Case 1

- Infiltrates worsen
- CXR deteriorates
- Hemodynamic instability requires large infusion of crystalloid
- Gas exchange deteriorates, requires FiO₂ 100% and HFPPV



Case 1

- Patient improves with HFPPV and diuresis
- Develops diplopia for unclear reasons which improves over 2 month period
- Returns to school

Case 2 Primary and Tertiary Blast Injury

- 73 yo former Pediatric Head Nurse
- Bus explosion Jan 29, 2003
- Admitted with SOB, chest pain
- Injuries:
 - Flail chest
 - Pulmonary contusion
 - Fracture right humerus
 - Traumatic bilateral finger amputations
 - Partial thickness facial burns



Case 2

- 10 days of mechanical ventilation
- 1 month of in hospital rehabilitation
- Prolonged recovery at home

Significant Risk of Left Sided Air Embolism

- Caused by alveolar-pulmonary venous fistula due to disruption of alveoli due to primary blast injury
- Possible Patent Foramen Ovale
- Risk increased with positive pressure ventilation
- Clinical manifestations
 - Blindness
 - “Hemiparesis
 - Paraplegia
 - Acute obstruction of other vascular beds

Evaluation of Patient for Air Embolism

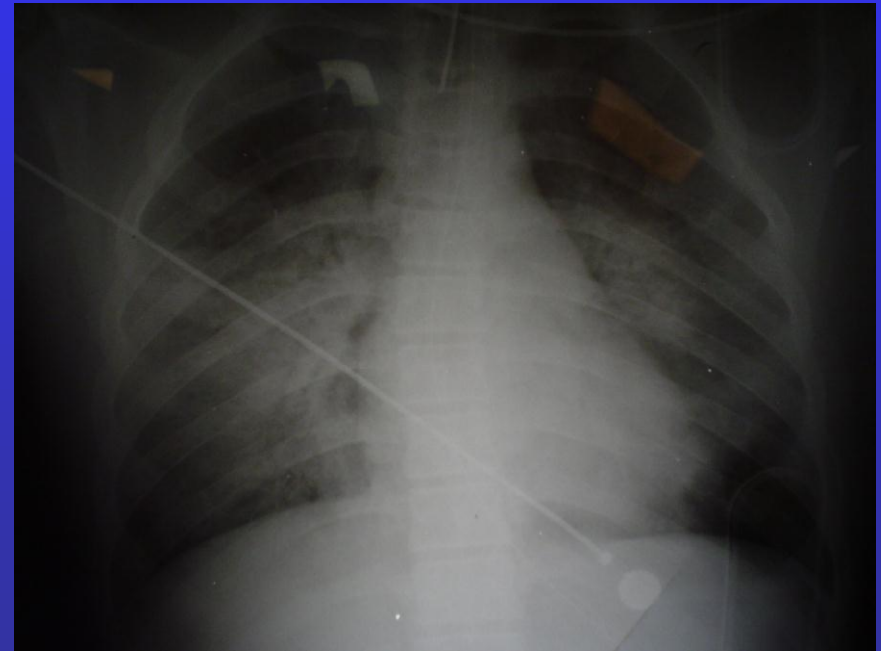
- Fundoscopic Exam – bubbles in retinal artery?
- Echocardiogram
- CT Head
- Most examinations are non-diagnostic

Treatment of Patient with Air Embolus

- Left Decubitus Position, Head Down, Feet Up
- Keep Peak Inspiratory Pressure Low if Patient Requires Mechanical Ventilation
- Hyperbaric Chamber

Case 3 Primary Blast Injury with Air Embolism and ? Intestinal injury

- 14 yo boy admitted in shock, unconscious with pH 7.0 and pCO₂ 70
- Intubated in ER and moved immediately to RR (secondary triage)
- Resp Status improves
- CT Chest and Abd ok except for pulm blast injury
- CT head ? Air embolus



Case 3 Hospital Course

- Resp Status remains stable
- Mental status begins to improve
- Dense left hemiparesis becomes evident

HD3

- BP becomes labile
- Vomits a small nail
- Abdominal rigidity develops
- KUB in the middle of the night suggests free air
- Dx of delayed intestinal perf due to blast injury or shrapnel injury
- Exp lap: **NORMAL**



Case 3

- Condition at discharge:
- Left hemiparesis
- Extremely labile
- 2 months later Hemiparesis almost completely resolved, playing soccer

Conclusions - 1

- BLI is a common serious injury among severely injured victims of closed space suicide explosions.

Conclusions - 2

- BLI often requires early mechanical ventilation.
- Clinically significant decompensation is unlikely after the first few hours.

Conclusions - 3

- Other blast injuries may occur and should be considered.

Conclusions - 4

- Death due to BLI is rare in patients who survive the initial explosion.