The Intensive Care of the Victim of Explosive Injury
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Objectives

- **Part 1: Mechanisms of Injury**
  - Understand the Basic Science and Applicable Specific Injury Patterns
- **Part 2: Patient Treatment**
  - Describe the Management and Care of Blast and Crush Injuries
- **Part 3: DISASTER Paradigm**
  - Apply Concepts Related to Explosives and Traumatic Events
- **Part 4: Clinical Issues and Pearls**
You know it’s going to be a bad day when....
Many thanks to the NDLS Series of Courses from the AMA for much of the following material.
Evolving Risks

for Simultaneous Events with Many, Many Casualties

- Population Densities
- Large Buildings
- Mass Transit
Nature of Explosions

Rapid chemical conversion of a solid or liquid into a gas with a resultant energy release.
Low and High Explosives:

Produce Forced Super-Heated Air Flow

EXPLOSIVES

LOW EXPLOSIVES

BLACK POWDER
SMOKELESS POWDER
FLASH POWDER

HIGH EXPLOSIVES

PRIMARY HIGH EXPLOSIVES

LEAD AZIDE
LEAD STYPhNATE
MERCURY FULMINATE
DDNP
TETRAZENE

SECONDARY HIGH EXPLOSIVES

BOOSTERS
PETN
RDX

MAIN CHARGE

DYNAMITE
BINARY EXPLOSIVES
WATER GELS
EMULSIONS
TNT

High Explosives Also Produce an Over-Pressurization Shock Wave
Explosions can produce unique patterns of injury seldom seen outside combat. When they do occur, they have the potential to inflict multi-system life-threatening injuries on many persons simultaneously.
<table>
<thead>
<tr>
<th>System</th>
<th>Injury or Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auditory</td>
<td>TM rupture, ossicular disruption, cochlear damage, foreign body</td>
</tr>
<tr>
<td>Eye, Orbit, Face</td>
<td>Perforated globe, foreign body, air embolism, fractures</td>
</tr>
<tr>
<td>Respiratory</td>
<td>Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, A-V fistulas (source of air embolism), airway epithelial damage, a spiration pneumonitis, sepsis</td>
</tr>
<tr>
<td>Digestive</td>
<td>Bowel perforation, hemorrhage, ruptured liver or spleen, sepsis, mesenteric ischemia from air embolism</td>
</tr>
<tr>
<td>Circulatory</td>
<td>Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury</td>
</tr>
<tr>
<td>CNS injury</td>
<td>Concussion, closed and open brain injury, stroke, spinal cord injury, air embolism-induced injury</td>
</tr>
<tr>
<td>Renal Injury</td>
<td>Renal contusion, laceration, acute renal failure due to rhabdomyolysis, hypotension, and hypovolemia</td>
</tr>
<tr>
<td>Extremity injury</td>
<td>Traumatic amputation, fractures, crush injuries, compartment syndrome, burns, cuts, lacerations, acute arterial occlusion, air embolism-induced injury</td>
</tr>
</tbody>
</table>
Part I
MECHANISMS of INJURY
Mechanisms of Injury

- Rapid Pressure Changes & Air Flow
- Rapid Heat Generation
- Falling Objects and Contaminants

...Can Result in “Triple Threat” of Blunt, Penetrating, Thermal Injuries in each patient

Also Can Have....

- Exacerbation of Existing Medical Conditions
- Psychological Trauma from the Event Itself
Mechanisms of Injury

Pressure and Air Flow
Phases of Positive and Negative Pressure

- Instantaneous Rise in Pressure
- Brisance or Shattering Ability
- Negative or Vacuum Effect

Image: Graph showing the phases of pressure with axes labeled 'Time' and 'Units of Pressure'.
Phases of Positive and Negative Pressure

- Peak “Overpressure” Damage Depends On:
  - Explosive Size
  - Distance from Blast
  - Surrounding Medium (water > air)
Phases of Positive and Negative Pressure

- Solid Surfaces Will Reflect and Magnify Blast Waves …
  (e.g., walls, corners, body armor)
Examples of Pressure Damage...

Positive ...  

Negative...
Mechanisms of Injury

Pressure Effects

Primary Blast Injury (PBI)

Results from “Blast Wave”
Primary Blast Injuries

Over-Pressurization Wave Impacts Body Surfaces

Causes Injuries to Gas-Filled Organs

- EARS
- LUNGS
- GI TRACT

...Also Causes Brain Injuries Without Physical Signs (concussion)
PBI: *Auditory System*

- Ruptured Tympanic Membranes
  *(most common ear injury)*
PBI: Auditory System

- Sensorineural Hearing Loss
  (middle and inner ear damage)
PBI: Auditory System

- Vertigo, Tinnitus, and Otalgia

......COMPLICATES TRIAGE
PBI: Lungs

Pressure Differentials:

- Tear Alveolar Walls
- Disrupt Alveolar-Capillary Interface

Discrete Contusions
Multi-Focal Hemorrhage
Hemo-Pneumothorax
Traumatic Emphysema
Subcutaneous Air
Alveolar-Venous Fistulæ (air emboli)
PBI: Lungs

“Blast lung”

• Second most susceptible organ
• Usually symptomatic immediately, can be delayed up to 48 hours
• Direct consequence of blast wave on the body
• Most common CRITICAL Injury in victims close to bomb
PBI: Lungs

“Blast lung”

• May not have obvious external injury to the chest
• Can be associated with pneumothorax, hemothorax
• Air embolism from pulmonary disruption (fatal)
PBI: Lungs

**Signs of Respiratory Distress:**
- Difficulty completing Sentences
- Rapid, Shallow Respirations
- Poor Chest Wall Expansion
- Decreased Breath Sounds
- Wheezing and/or Hemoptysis
- Cutaneous Emphysema
PBI: Lungs

CXR: Characteristic “Butterfly” Pattern
FIGURE 204 (case 5).—Serial roentgenograms in blast injury. A. Posteroanterior roentgenogram, 11 November 1943, 24 hours after injury, showing diffuse bilateral haziness and infiltration indicative of petechial pulmonary hemorrhage and edema. B. Posteroanterior roentgenogram, 17 November 1943, showing clearing of lung field. C. Posteroanterior roentgenogram, 7 January 1960, 16 years after severe blast injury. The only abnormality is slight emphysema of upper lobes. The diaphragms are at level of the eleventh ribs; their contours are rounded. Heart is also normal.
PBI: Lungs

Also: Systemic Air Embolism

- Most Common Cause of PBI - Related Sudden Deaths Over the 1st hour
- Direct Leak Between Pulmonary Vasculature & Bronchial Tree
- Low Venous Pressure and High Airway Pressure Creates Pressure Gradient
- Decompensation is Often Immediately after Endotracheal Intubation and Use of Positive Pressure Ventilation (PPV)
PBI: *Lungs*

**Systemic Air Embolism**

- Vascular Obstruction...
  
  ...*referable to location of occlusion:*
  
  - Chest pain (coronary symptoms)
  - Focal Neurological Deficit
  - Blindness
  - Tongue Blanching
  - Skin changes
Fatal Diffuse Cerebral Air Embolism
PBI: Lungs

- Standard Trauma triage, resuscitation protocols
  - management like that of pulmonary contusion in trauma
  - judicious fluid use for adequate organ perfusion without overload
  - Oxygen- from high flow, non-rebreather mask to CPAP or intubation
  - May benefit from selective (double lumen) tube
  - Positive Pressure ventilation may increase risk of alveolar rupture and air embolism
  - Ventilation – High frequency Jet ventilation
    - Permissive hypercapnia
PBI: GI System

- Involves Gas - Containing Abdominal Structures
  - Colon \textit{(more air)} Involved > Small Bowel
- Acute or Delayed Rupture Seen
  - Due to stretching & ischemic bowel wall weakening
  - Shear Forces May Tear Mesentery

\textbf{Still...}

\textit{Abdominal Injuries More Likely from Usual Blunt & Penetrating Mechanisms}
PBI: GI System

**Signs & Symptoms:**
- Abdominal Pain
- Nausea / Vomiting
- Diarrhea / Tenesmus
- Rebound and Guarding
- Decreased Bowel Sounds
- Free Air on X-Ray
PBI: GI System

– Colon – visceral organ most frequently affected
– Mesenteric ischemia from gas embolism may cause delayed rupture of large or small intestine
– Intestinal barotrauma more common with underwater air blast
– Solid organ injury less likely
– Signs and symptoms
  • Abdominal pain, nausea, vomiting, hematemesis
  • Rectal pain and tenesmus
  • Testicular pain
  • Unexplained hypovolemia
Intestinal Mucosal Edema
PBI: Other Organs

• Eye
  – Globe rupture, serous retinitis, hyphema, lid laceration, traumatic cataracts, injury to optic nerve
  – Signs and symptoms include eye pain, foreign body sensation, blurred vision, decreased vision, drainage
PBI: Other Organs

- **Brain**
  - TBI due to barotrauma or gas embolism
  - Signs and symptoms include headache, fatigue, poor concentration, lethargy, anxiety, and insomnia
  - AMS or coma may result
Mechanisms of Injury

*Air Flow Effects*

Secondary *and* Tertiary Blast Injuries

Results from “*Air Rush*”
Secondary Blast Injuries

...Caused by Flying Debris & Bomb Fragments

- Result in Blunt Injuries and...
- Penetrating Ballistic Injuries

...from fragmentation

...Actually Responsible for the Majority of Casualties
Secondary Blast Injuries

- Deliberately Placed Metal Objects
- Effect Increased in Enclosed Spaces
- **DO NOT FORGET THE EYES!**
Secondary Blast Injuries

Penetrating & Blunt Injuries:
Tertiary Blast Injury

- Patient Becomes a Missile
- Impaled or Hits a Hard Surface
- Can Result in Penetrating and Blunt Injuries
SO TO SUMMARIZE
BLAST INJURIES...
Primary Pressure Wave Injuries
(... ears, lungs, abdomen, head, etc)
Primary Pressure Wave Injuries
(... ears, lungs, abdomen, head, etc)

Secondary Blast Injuries
(missiles, blast fragments, etc)
Secondary Blast Injuries (missiles, blast fragments, etc)

Tertiary Blast Injuries (from impalement or landing on hard surface, sharp objects, etc)

Primary Pressure Wave Injuries (...ears, lungs, abdomen, head, etc)
Mechanisms of Injury
Other Effects

Quaternary Blast Injuries

Result from heat, crush, contaminants, exacerbations of underlying illness...
Mechanisms of Injury

Heat

1st Degree Burns
2nd Degree Burns
3rd Degree Burns

Burns May Be Partial or Full Thickness
Airway Involvement Is a Major Concern
Mechanisms of Injury

FALLING OBJECTS

Including structural collapses, blast debris
Mechanisms of Injury

Falling Objects

Major Concerns:

• Traumatic Asphyxia
• Crush Injuries
• Compartment Syndrome
Traumatic Asphyxia

Common after Structural Collapse ...
Traumatic Asphyxia

...and Crowd Surge
Traumatic Asphyxia

- Main Effect is Chest Compression
  - Leads to Respiratory Embarrassment
  - Impedes Blood Flow into Thorax
  - Retrograde Blood Flow
  - Back Pressure Transmitted to Great Veins of Head and Neck
- Children More Vulnerable
  - More Pliable Cartilaginous Chest
Traumatic Asphyxia

Dramatic Presentation...

- Respiratory Distress
- Chest Ecchymoses, Diffuse Petechiae
- Facial Edema and Cyanosis
- Subconjunctival, Retinal Hemorrhage
- Signs of Cerebral Anoxia (e.g., altered mental status, seizure and coma)

...but can be benign, self-limited
Crush Injury

Common after Structural Collapse …

…Sustained Large Muscle Compression
Compartment Syndrome

- Ecchymoses, Tenderness, Swelling,
- Pain with Passive Motion
- Numbness, Weakness & Paralysis
- Does the presence of a pulse rule-out a compartment syndrome?
Crush Injury

• Traumatic Rhabdomyolysis
• Releases Intracellular Toxins
  – Sodium, Calcium, Water Shift Into Damaged Muscle Cells
  – Potassium, Phosphate, Lactate, Myoglobin Shift Out of Cells
• Potentially Toxic When Circulated through the Blood Stream
Crush Syndrome

• Reperfusion Injury ...Upon Extrication
• Rapid Hyperkalemia is Cardiotoxic
• Hyperphosphatemia causes Hypocalcemia
  ...Self-limited, but may cause tetany / seizure
• Massive Fluid Sequestration
• Shock !
  ...Dramatic 3rd Spacing ("hypovolemia")
  & Neg. Inotropic effects = Profound Shock
Crush Syndrome

Diagnostic Testing

• Hypermyoglobinemia
  - Pinkish Serum
  - Tea - Colored Urine

• Renal Failure

• EKG
  - May Show Signs of Hyperkalemic Toxicity
  - Peaked T - Waves
  - Wide QRS (> 0.12 sec)
Peaked T Waves
from Hyperkalemia
Mechanisms of Injury

CONTAMINANTS

(Smoke; Hazardous Materials, including “Dirty Bombs”)
Mechanisms of Injury

Contaminants

• Industrial Incidents
• Transportation Mishaps
Mechanisms of Injury

EXACERBATION OF EXISTING MEDICAL CONDITIONS
Mechanisms of Injury
Worsened Medical Conditions

- Angina
- Asthma
- COPD
- Hypertension

...and other chronic health problems
Mechanisms of Injury

PSYCHOLOGICAL IMPACT

(the "event" itself)
Mechanisms of Injury

Psychological Reactions

Acute Stress Reactions

Post-Traumatic Stress Disorders
TREATMENT of Blast Injuries
Treatment of Blast Injury

• Maintain High Index of Suspicion for Occult Injury
• Expect Multiple Mechanisms of Injury in a Single Patient

• **Remember:** The Victim May Not Be Able to Hear you!
A-B-C: Airway

- Protect & Secure the Airway
- Consider Need for Cervical Spine Immobilization
Breathing

• Support Oxygenation
  100% Supplemental O₂
• ATLS Chest Trauma Guidelines
• If Primary Blast Injury Suspected:
  – Minimize Pt. Activity
  – Spontaneous Breathing Preferred
  – Avoid Overzealous Assisted Ventilation
• Consider Prophylactic Chest Tubes
  Prior to PPV and/or Air Transport
Circulation

- Control Overt External Hemorrhage
- Evacuate to a Trauma Center
- Consider Intravascular Volume

- Consider Air Embolism...
Air Embolism

Treatment

- Spontaneous Respiration Preferred
  - Especially if at Risk for Systemic Air Embolism
- Oxygen
  - Oxygen Improves Bubble Resorption (Nitrogen shift)
  - Hyperbaric O2 Rx May Be Effective
- Keep Airway Pressure < Vascular Pressure
  - Key: Maximize Preload & Minimize Barotrauma
- Delay Any Non-Emergent Surgery
Treatment of Penetrations

- Example of How Mechanism of Injury is VIP in Decision to Transport to a Trauma Center
  - Entry Wounds
    - Can Be Deceptive
  - Need Expert Exploration
Treatment of Burns

- Standard Burn Center Guidelines
- Stop Any Continued Burning, Assess ABC’s
- Anticipate Hypovolemia and Heat Loss
- Dress the Burns – Clean, Dry Dressing
- Evacuate to Appropriate Facility
Treatment of Burns

Parkland Burn Formula: 4 cc. per kg. body weight per % deep burn during the first 24 hours

1. To calculate: multiply 4 X kg. X % burn = total fluid requirement

2. Give half of this amount during the first 8 hours from the time of injury
Treatment of Traumatic Asphyxia

- Most Important Factor Impacting Survival is Rapid Extrication and Release
- Look for Associated Life-Threatening Injuries
Treatment of Crush Syndrome

- Treat Suspected Hyperkalemia if Clinical & EKG Evidence of Cardiotoxicity, consider:
  - IV Fluids (Normal Saline Preferred over LR)
  - IV Glucose and Insulin
  - Sodium Bicarb
  - Inhaled Beta-2 Agonist (albuterol)
  - Calcium Chloride if unstable
  - Dialysis
  - Consider Exchange Resin (Kayexalate)
  - Mannitol for diuresis (Risks/Benefits)
Treatment of Contaminants

- Decontamination
- Personal Protective Equipment Use to Avoid Rescuer Exposure
- Oxygen Therapy
- Consider Toxins and Smoke Inhalation (e.g. Carbon Monoxide, Cyanide, etc…)
- Poison Control Center
- Parkland Case Example
Treatment of Underlying Medical Conditions

Approach the Same as in Non-Explosive Situations
DISASTER PARADIGM
D: Detection

I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Detection

- Conventional Explosives are the Most Commonly Utilized Weapons
- Easy to detect: “Something exploded”
- Hard to detect: Secondary device
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Incident Command

- Coordinated Scene Effort with Law Enforcement, Fire-Rescue, & EMS

- Hospital ICS must be coordinated with overall ICS
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Scene Safety & Security

- Inherent Hazards to Medical Responders
- Do Not Enter Unstable Structures
- Restrict Access to the Scene
- Contaminated Scene?
  - Radiological “Dirty”
  - Chemical, Biological, etc..
- Caution! Secondary Devices!
  - Radio Communication May Cause Secondary Device Detonation
  - Do Not Touch Electronic Equipment Found at Scene *(may be detonator)*
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Support

Consider...

• HAZMAT, EOD, Mortuaries, USAR, Radiological Safety Personnel, Industry, Media, etc..

• State, Federal, Military Resources
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
MASS Triage

Remember:

● Hearing Impairment Is Common
  ...may lead to incorrect triage

● Rapidly Evacuate Entire Scene
  ...moving to safety may save lives!
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Ground Evacuation

Need to Ask ....

- Am I Transporting a “Contaminated” Pt. ?
- Is Further Decontamination Required?
- Is this the Best Method of Transportation?
Air Evacuation

- Limited Resource
- Worsens Barotrauma?
- Oxygenation Can Worsen with Altitude
- Precautionary Tube Thoracostomy?
D: Detection
I: Incident Command
S: Safety & Security
A: Assess Hazards
S: Support
T: Triage & Treatment
E: Evacuation
R: Recovery
Recovery

- Should Begin Immediately!
  - Economic
  - Physical
  - Psychological
ICU Specifics
Approaching the Patient
“See what you see!”

“People look, but they don’t see”  
...A. Fowler, Jr.
Alertness?
Level of distress?
Noises?
Respirations?
The pulse rate?
Skin?
Obvious things (bleeding)
The "art" of medicine is missing from so many practitioners...

...are they not looking, or have they lost interest?
History Taking:

This seems to be a “lost black art” for so many medical providers

What happened?
When?
LOC?
Major system symptoms?
Co-morbid conditions?

Above all: RISK???
Basic Physiology of Critical Care Medicine

Relates to the Physical Findings

The Initial Assessment: LOC/ABC
Scene Survey/Mechanism/# pts.

LOC/Airway/Cspine

Respiratory Rate and Labor

Pulses R & Q, N & W
Skin CMT/CRT/External Bleeding

Neck appearance, JVD, Trachea

Chest appearance, BS, HT

Quick survey of abdomen, pelvis, extremities, and back
Scene Survey/Mechanism/# pts.
LOC/Airway/Cspine
Respiratory Rate and Labor
Pulses R & Q, N & W
Skin CMT/CRT/External Bleeding
Neck appearance, JVD, Trachea
Chest appearance, BS, HT
Quick survey of abdomen, pelvis, and extremities

Reveals threats to Basic Physiology

...the vital elements of the Primary Survey
Shock
Blood pressure = Cardiac output × Peripheral resistance
Blood pressure =

\[ \text{Pump} \times \text{fluids} \times \text{pipes} \]
What does a low blood pressure mean?

Either...

Or a combination of any of these
Signs of Shock

Early
- Weak, thirsty, lightheaded
- Pale, then sweaty
- Tachycardia
- Tachypnea
- Diminished urinary output

Late
- Hypotension
- Altered LOC
- Cardiac arrest
- Death
What is the problem with shock?

Oxygen deprivation to the tissues below an absolute level of about 10 mmHg at the tissue level, causing cell membrane damage, ion depolarization, and calcium shifts with cell death.
Three Types of Shock

**Heart:** Cardiogenic, or mechanical

**Volume:** Low volume

**Vasodilatory:** High space
Shock

Cardiogenic
- Rapid pulse
- Distended neck veins
- Cyanosis

Volume Loss
- Rapid pulse
- Flat neck veins
- Pale

Vasodilatory
- Variable pulse
- Flat neck veins
- Pale or pink
### Injury Severity Scores

#### ISS - RTS - TRISS

*(Injury Severity Score - Revised Trauma Score - Trauma Injury Severity Score)*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Severity level (help)</th>
<th>Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and neck</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Face</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Abdomen, pelvic contents</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Extremity, pelvic girdle</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>External</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**ISS** = 0

| Respiratory rate (per min)    |                       | 0      |
| Systolic blood pressure (mmHg)|                       | 0      |
| Glasgow coma scale (help)     |                       | 0      |

**RTS** = 0

| Age                           |                       | 0      |

(Pediatric cases (Ages < 15) use the blunt model for both blunt and penetrating mechanisms of injury.)

<table>
<thead>
<tr>
<th>Predicted death rate (blunt)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TRISS</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TRISS** (blunt): Logit = -0.4499 + RTS*0.8085 + ISS*0.0836 + (age points)*-1.7430
Predicted death rate = 1/(1 + e-logit)

<table>
<thead>
<tr>
<th>Predicted death rate (penetrating)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TRISS (penetrating): Logit = -2.6355 + RTS<em>0.9934 + ISS</em>0.0651 + (age points)*-1.1360</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Predicted death rate = 1/(1 + e-logit)
Revised Trauma Score

<table>
<thead>
<tr>
<th>Glasgow Coma Scale (GCS)</th>
<th>Systolic Blood Pressure (SBP)</th>
<th>Respiratory Rate (RR)</th>
<th>Coded Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-15</td>
<td>&gt;89</td>
<td>10-29</td>
<td>4</td>
</tr>
<tr>
<td>9-12</td>
<td>76-89</td>
<td>&gt;29</td>
<td>3</td>
</tr>
<tr>
<td>6-8</td>
<td>50-75</td>
<td>6-9</td>
<td>2</td>
</tr>
<tr>
<td>4-5</td>
<td>1-49</td>
<td>1-5</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Survival Probability by Revised Trauma Score

- Survival Probability vs Revised Trauma Score (RTS)
- Probability values for each RTS level: 0.027, 0.071, 0.172, 0.361, 0.605, 0.807, 0.919, 0.969, 0.988
Penetrating Abdominal and Lower Thoracic Trauma
Thoracic Aneurysm
Shock Management

In the setting of uncontrolled hemorrhage, low volume resuscitation seems appropriate, maintaining peripheral pulses.
Post Cardiac Arrest

The era of induced hypothermia for brain preservation post cardiac arrest is here, and you and your teams should be exploring this... beginning in the EMS area!
Ventilation and Critical Care
Oxygen -> lungs -> alveoli -> blood

muscles + organs

Oxygen + Glucose

energy

CO₂

breath

CO₂

blood

lungs

Physiology
Need to Ventilate

- CO₂ Production
  \((O₂ \text{ Consumption} \& \text{ Venous Return})\)

- Airway Dead Space
  \((\text{wasted ventilation})\)
Speed of Ventilation

- CO₂ Production
  (O₂ Consumption & Venous Return)

- Airway Dead Space
  (wasted ventilation)
Generally speaking:

The patient in circulatory collapse suffers greatly from positive pressure ventilation.
The negative pressure inside the thorax “pulls” blood back from the positive pressure areas.
Positive Pressure in the Thorax decreases Venous Return!!
Breathing the patient too fast INCREASES pressure inside the chest!
Do YOU make a judgment as to how fast to bag your patients who are critically ill?
The Bedside Accuracy of Respiratory Adequacy

Fowler, Pepe et al.
Failure of Respiratory Rate to Predict Capnography Levels.
MEMCIV, September 2007.
EMS Patients with pulses

Respirations vs. Capnography

\[ y = -0.2947x + 41.906 \]
Cardiac Arrest Victims

Capnography vs. Respirations in Cardiac Arrest

Capnography

Respiratory Rate
...and regarding airway management...
Multivariate Predictors of Failed Prehospital Endotracheal Intubation

Henry E. Wang, MD, Douglas F. Kupas, MD, Paul M. Paris, MD, Robyn R. Bates, MS, Joseph P. Costantino, DrPH and Donald M. Yealy, MD

From the Department of Emergency Medicine, University of Pittsburgh School of Medicine (HEW, PMP, RRB, DMY), Pittsburgh, PA; the Department of Emergency Medicine, Geisinger Health System (DFK), Danville, PA; and the Department of Biostatistics, Graduate School of Public Health, University of Pittsburgh (JPC), Pittsburgh, PA.
Of 61 factors potentially related to ETI failure, multivariate logistic regression revealed the following significant covariates associated with ETI failure (odds ratio; 95% confidence interval; likelihood ratio p-value):

- **presence of clenched jaw/trismus**  
  \(9.718; 95\% \text{ CI} = 4.594 \text{ to } 20.558; p < 0.0001\);

- **inability to pass the endotracheal tube through the vocal cords**  
  \(7.653; 95\% \text{ CI} = 3.561 \text{ to } 16.447; p < 0.0001\);

- **inability to visualize the vocal cords**  
  \(7.638; 95\% \text{ CI} = 3.966 \text{ to } 14.707; p < 0.0001\);

- **intact gag reflex**  
  \(7.060; 95\% \text{ CI} = 3.552 \text{ to } 14.033; p < 0.0001\);

- **intravenous access established prior to ETI attempt**  
  \(3.180; 95\% \text{ CI} = 1.640 \text{ to } 6.164; p = 0.0005\);

- **increased weight (ordinal scale)**  
  \(1.555; 95\% \text{ CI} = 1.242 \text{ to } 1.947; p = 0.0001\);

- **electrocardiographic monitoring established prior to ETI attempt**  
  \(0.199; 95\% \text{ CI} = 0.084 \text{ to } 0.469; p = 0.0003\).
Traumatic Brain Injury
Hyperventilation appears to decrease the blood flow to the injured areas of the brain and thus does not appear to be indicated in most circumstances.
Hypertonic Saline: Extensive work, including the by the Resuscitation Outcomes Consortium, suggests that we should actively work to prevent brain swelling early.
Clues to Worsening Patients in the ICU
Worsening mental status
Increased work of breathing

OR

decreased work of breathing with worsening mental status
Worsening oxygenation: Especially in the setting of increased or decreased work of breathing.
Worsening oxygenation: Common in the blast lung situation
BEWARE!!!!

Positive pressure ventilation in the setting of blast lung can worsen chances of systemic air emboli!!!
Fowler’s Law of Breathing:

*Work of breathing decreases for two reasons – Good and Bad*
Extremes of capnography:
Significantly outside the range of 35 to 45
Unexplained acidosis after explosion: 

*Think Shock*
*Think Cyanide*
Cyanide blocks energy production and oxygen utilization in the mitochondria.
Unexplained AMS after explosion:  
*Think Air Embolism*
Multi Organ Dysfunction Syndrome
Multiorgan dysfunction syndrome (MODS) is one of the most frequent conditions encountered in intensive-care medicine. MODS is defined as total or partial loss of two or more organs with vital functions.
Dissolved substances involved in the regulation of regional blood flow, endothelial cell injury, microvascular permeability, oxygenation, and nutrition of cells are at the focus of interest in MODS.
The development of acute renal failure (ARF) in MODS leads to an additional aggravation with considerably higher hospital mortality than in other ICU patients with MODS.
An impaired renal water excretion and an increased metabolic water volume requiring excretion interfere with diffusive and convective oxygen transport through the different fluid compartments.
Hyperhydration in renal failure begins primarily with an intravascular volume increase.
Clinical parameters assessing intravascular water volume are either too unspecific or too insensitive to estimate the actual hydration status.
A unique exception regarding its specificity is the ratio of urine to plasma osmolality (Uosm/ Posm).
The ratio of $\text{Uosm}/\text{Posm}$ appears to be a reliable tool to assess overhydration in Acute Renal Failure.
Consider the urinary output as related to water intake, remembering that water output also reflects protein metabolism in the body.
Sepsis usually generates a high cardiac output with a fall in systemic vascular resistance.
Clues to “Dirty Bombs”

Irradiation

External Contamination

Internal Contamination
<table>
<thead>
<tr>
<th>Condition</th>
<th>Threshold (Gy)</th>
<th>ED&lt;sub&gt;50&lt;/sub&gt; (Gy)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligospermia (2 Yrs)</td>
<td>0.3</td>
<td>0.7</td>
</tr>
<tr>
<td>Ovulation Suppression (permanent)</td>
<td>0.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Vomiting</td>
<td>0.5</td>
<td>2</td>
</tr>
<tr>
<td>Diarrhea</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Mortality from Marrow Syndrome (minimal care)</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>Mortality from Marrow Syndrome (supportive care)</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td>Thyroiditis</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Skin - Erythema</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Skin - Dry Desquamation</td>
<td>5 - 20</td>
<td>20</td>
</tr>
<tr>
<td>Skin - Wet Desquamation</td>
<td>12 - 20</td>
<td>-</td>
</tr>
<tr>
<td>Skin - Necrosis</td>
<td>20 - 30</td>
<td>-</td>
</tr>
<tr>
<td>Mortality from Pulmonary Syndrome Lethality</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Mortality from Gastrointestinal Injury</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>CNS Incapacitation</td>
<td>6.5</td>
<td>17</td>
</tr>
<tr>
<td>Acute Encephalopathy</td>
<td>5 - 8</td>
<td>-</td>
</tr>
</tbody>
</table>
Hemogram
(300 cGy TBI Exposure)
Synthesis
The requirement for professionalism in the Practice of Medicine Continues to Grow Unceasingly
The scope and breadth of your practice will be limited only by your imagination.
Summary

- **Mechanisms of Injury**
  - Unique aspects of blasts
- **Patient Treatment**
  - ATLS / BTLS Guidelines
- **DISASTER Paradigm**
  - High Risk Environment for 2nd Pass: Secondary Devices, Unstable Structures, Contaminant Release, Secondary Fires, etc…
Questions?