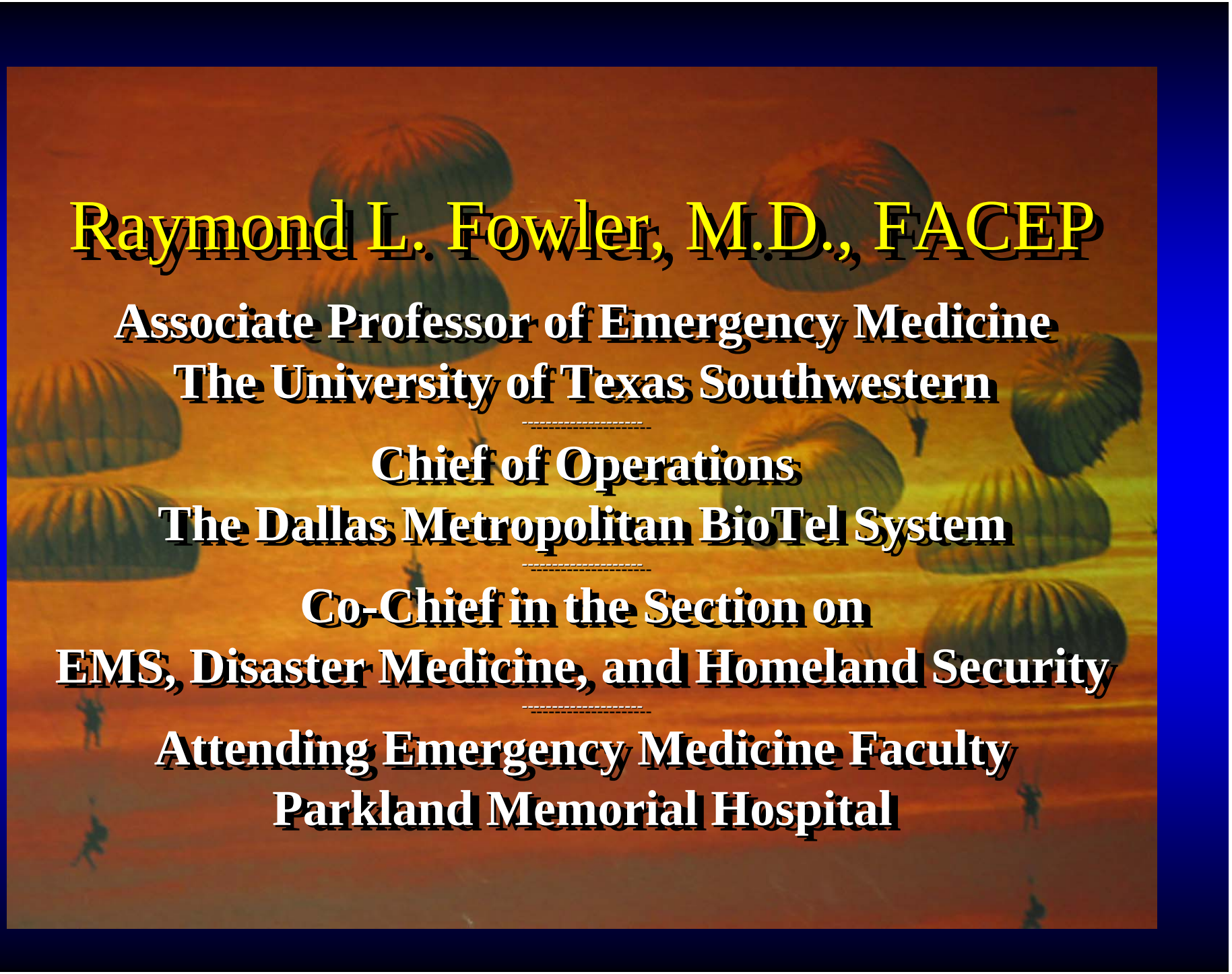

The Intensive Care
of the Victim of
Explosive Injury


Raymond L. Fowler, M.D., FACEP
Associate Professor of Emergency Medicine
The University of Texas Southwestern
Chief of Operations
The Dallas Metropolitan BioTel System
Co-Chief in the Section on
EMS, Disaster Medicine, and Homeland Security
Attending Emergency Medicine Faculty
Parkland Memorial Hospital

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**


PARKLAND EMERGENCY & TRAUMA

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

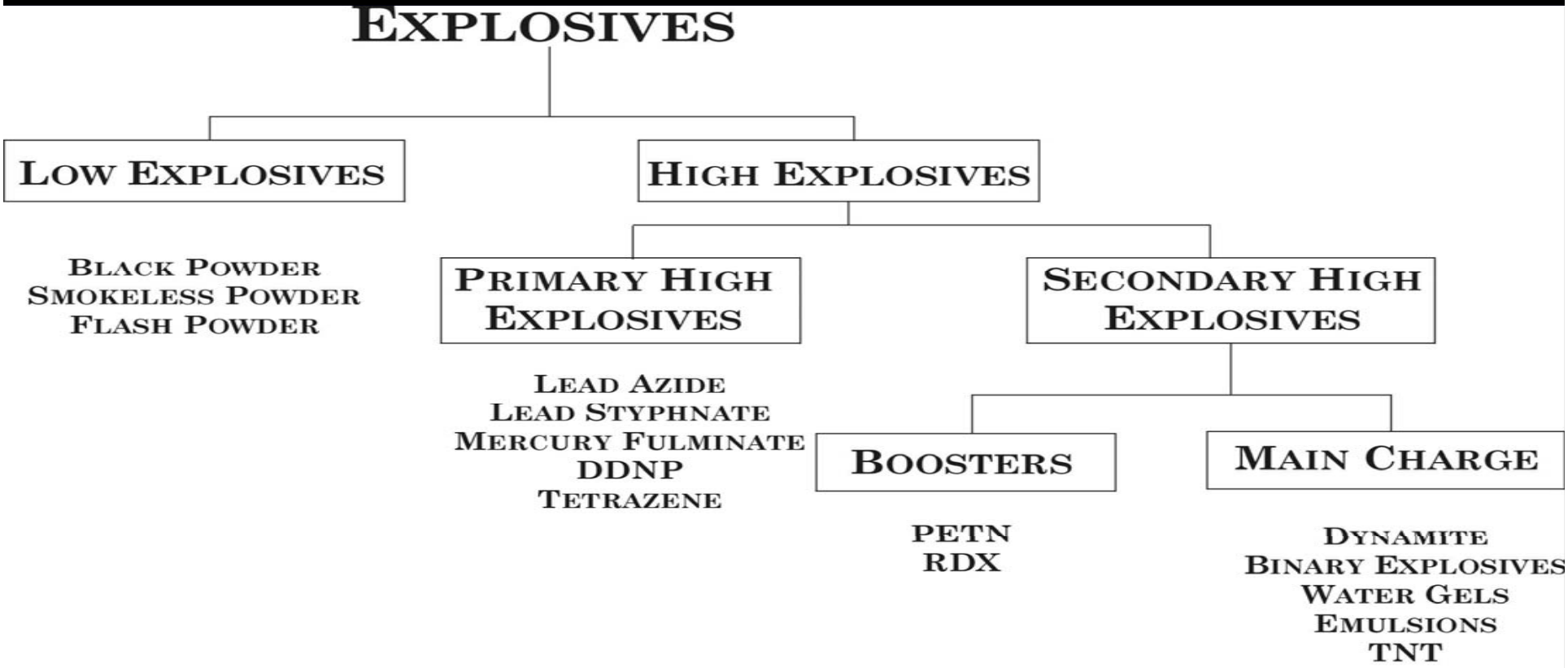
*for **Simultaneous Events** with **Many, Many Casualties***

- **Population Densities**
- **Large Buildings**
- **Mass Transit**

Nature of Explosions

Low and High Explosives:

Produce Forced Super-Heated Air Flow

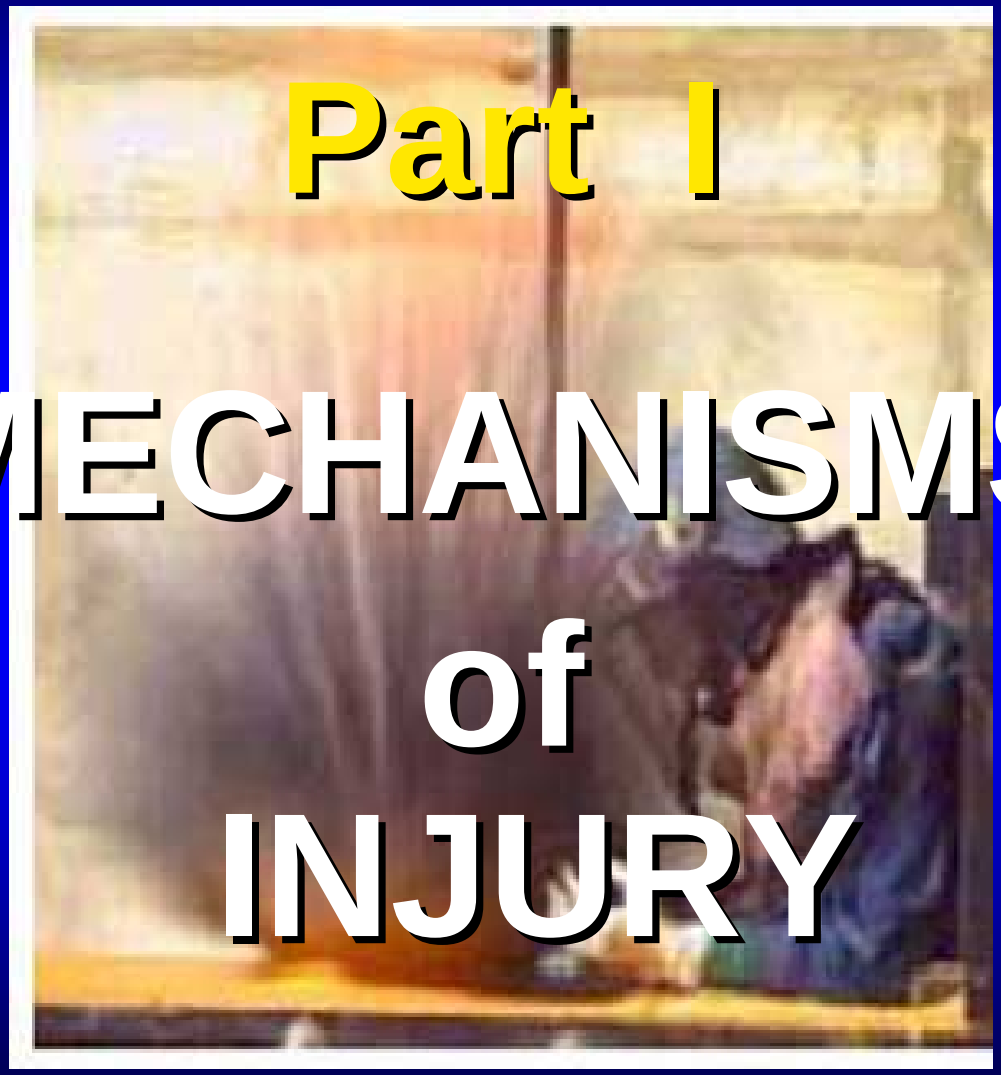


High Explosives Also Produce an Over-Pressurization Shock Wave

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.

System	Injury or Condition
Auditory	TM rupture, ossicular disruption, cochlear damage, foreign body
Eye, Orbit, Face	Perforated globe, foreign body, air embolism, fractures
Respiratory	Blast lung, hemothorax, pneumothorax, pulmonary contusion and hemorrhage, A-V fistulas (source of air embolism), airway epithelial damage, a spiration pneumonitis, sepsis
Digestive	Bowel perforation, hemorrhage, ruptured liver or spleen, sepsis, mesenteric ischemia from air embolism
Circulatory	Cardiac contusion, myocardial infarction from air embolism, shock, vasovagal hypotension, peripheral vascular injury, air embolism-induced injury
CNS injury	Concussion, closed and open brain injury, stroke, spinal cord injury, air embolism-induced injury
Renal Injury	Renal contusion, laceration, acute renal failure due to rhabdomyolysis, hypotension, and hypovolemia
Extremity injury	Traumatic amputation, fractures, crush injuries, compartment syndrome, burns, cuts, lacerations, acute arterial occlusion, air embolism-induced injury



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

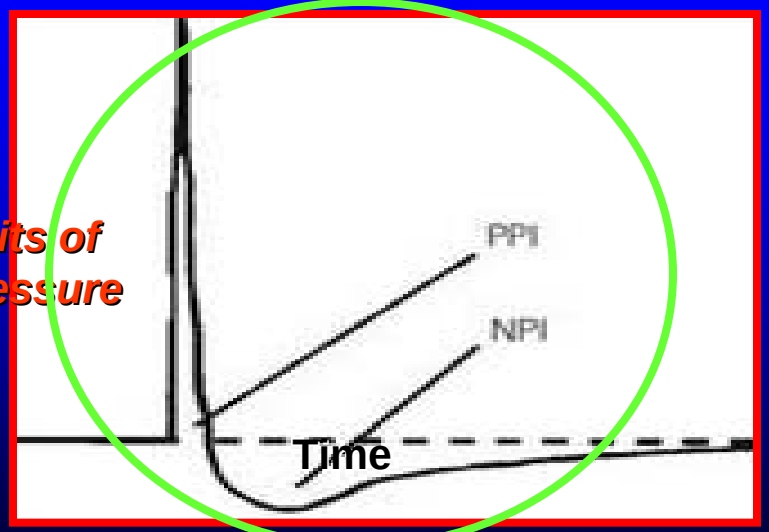
Pressure and Air Flow

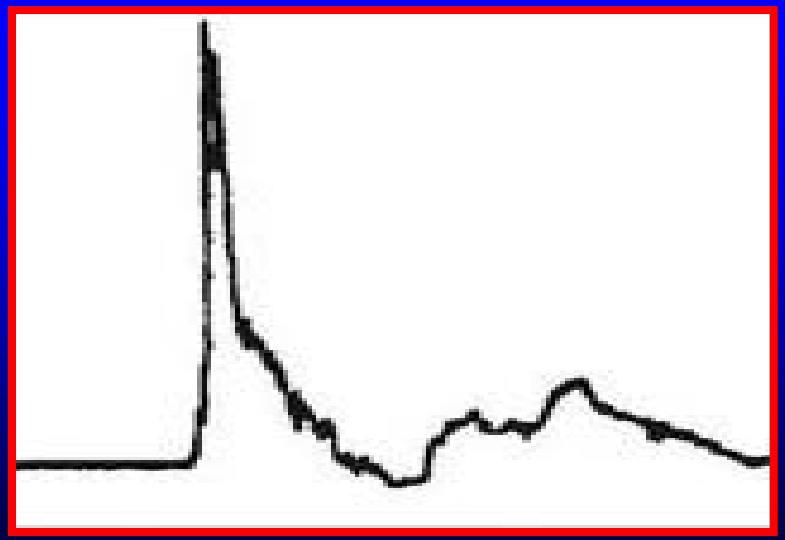
Phases of Positive and Negative Pressure

Instantaneous Rise in Pressure

Brisance or Shattering Ability

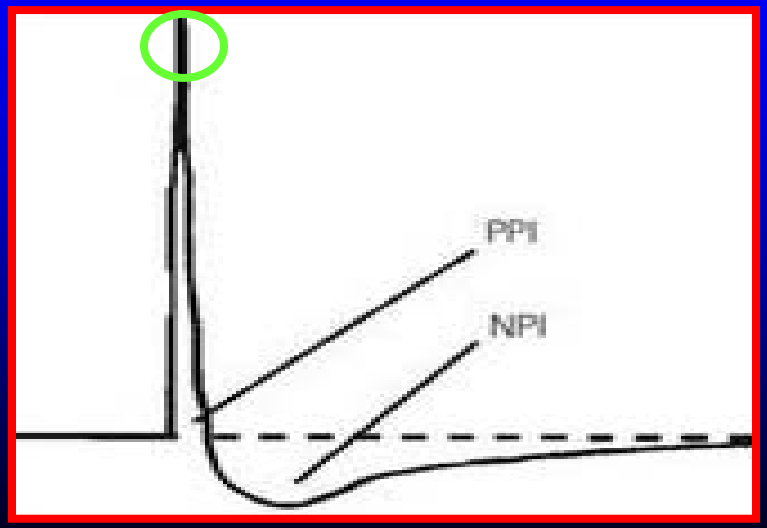
Negative or Vacuum Effect

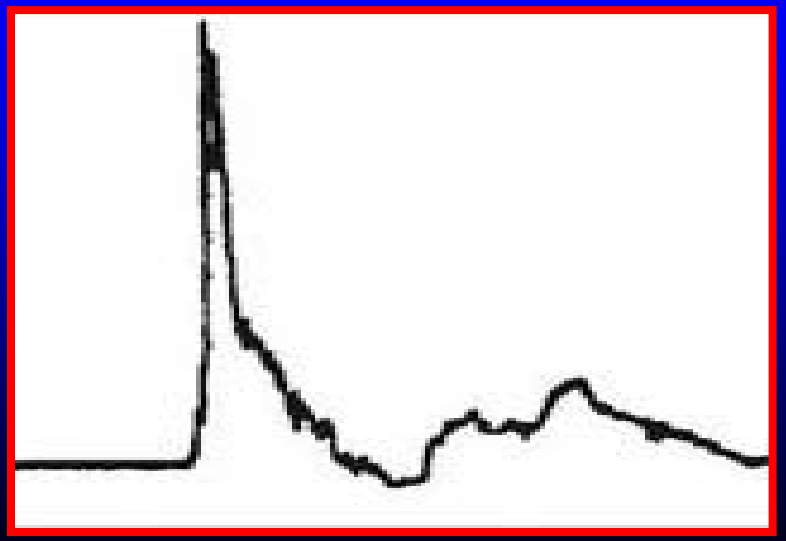




Phases of Positive and Negative Pressure

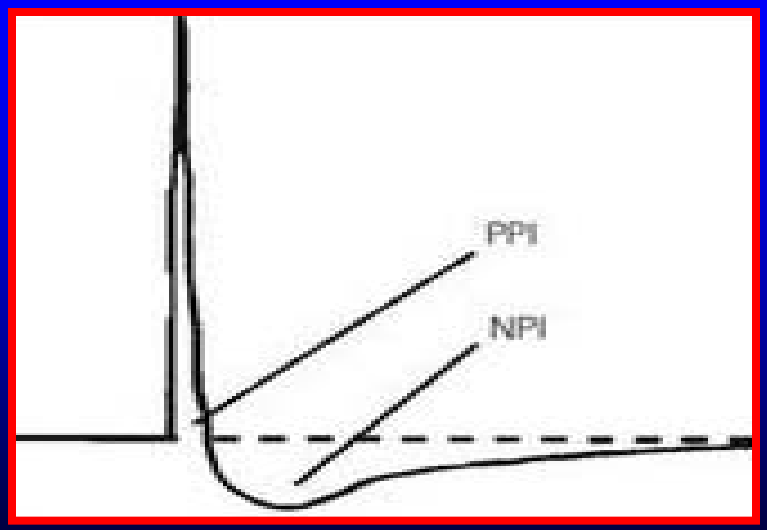
- **Peak "Overpressure" Damage Depends On:**
  - **Explosive Size**
  - **Distance from Blast**
  - **Surrounding Medium (water > air)**

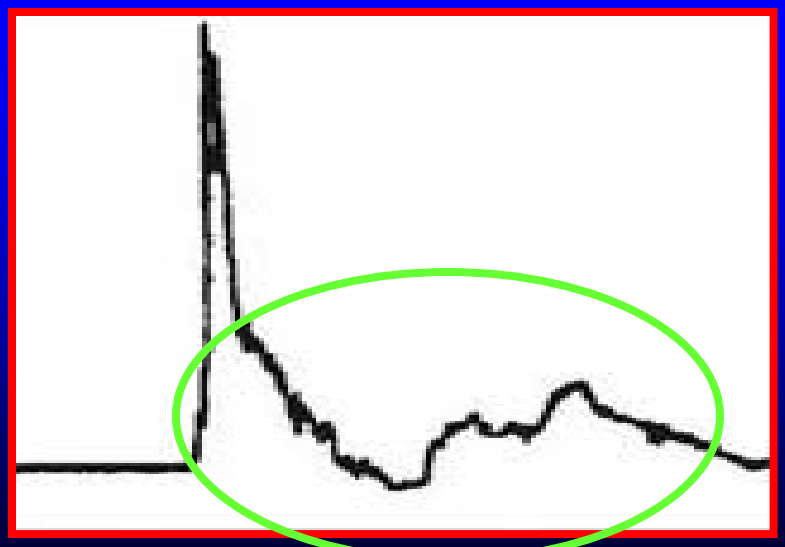




Phases of Positive and Negative Pressure

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





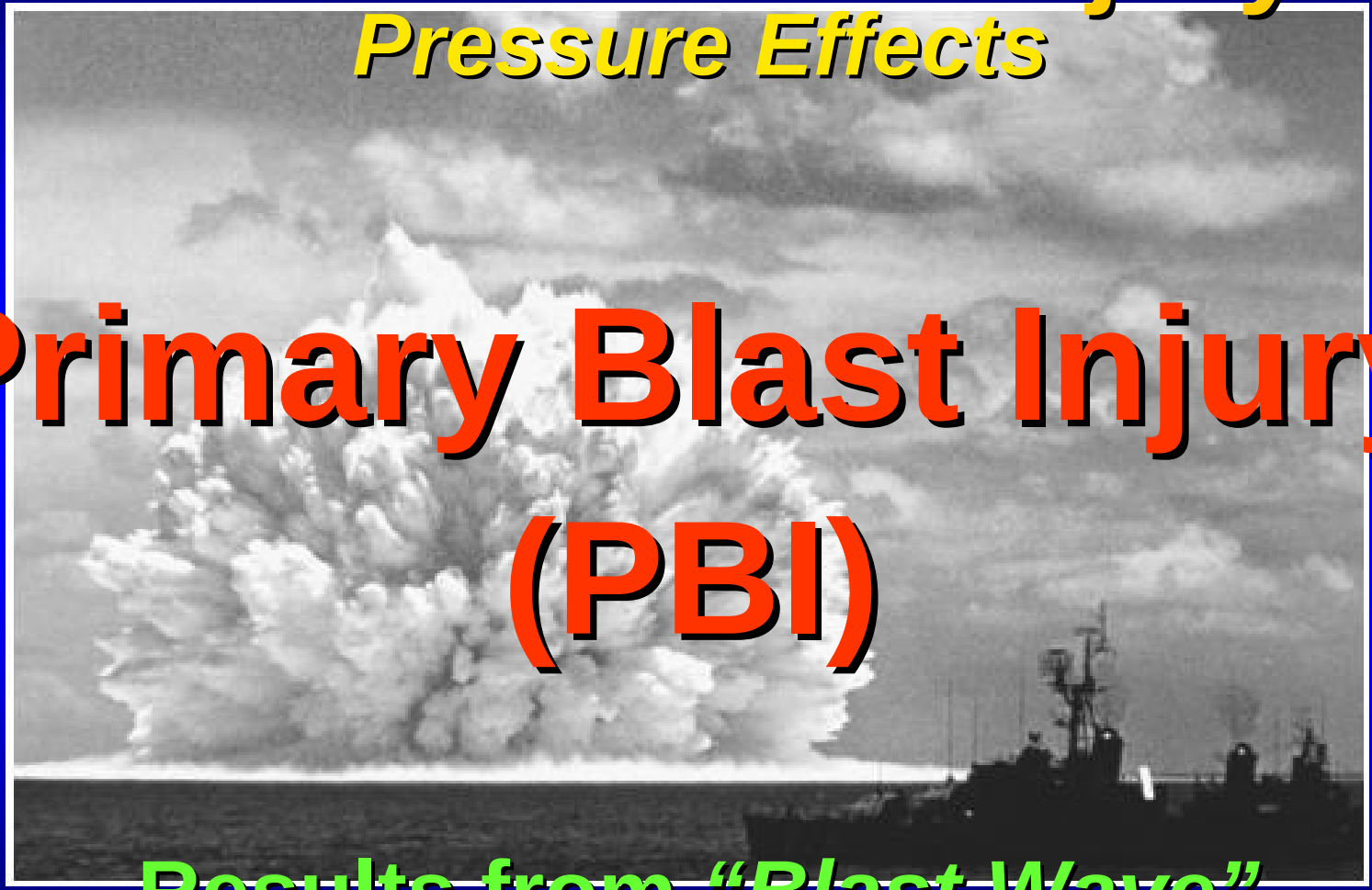
Examples of Pressure Damage…

Positive …

Negative…

Mechanisms of Injury

Pressure Effects



Primary Blast Injury (PBI)

Results from *"Blast Wave"*

Primary Blast Injuries

…Over-Pressurization Wave Impacts Body Surfaces

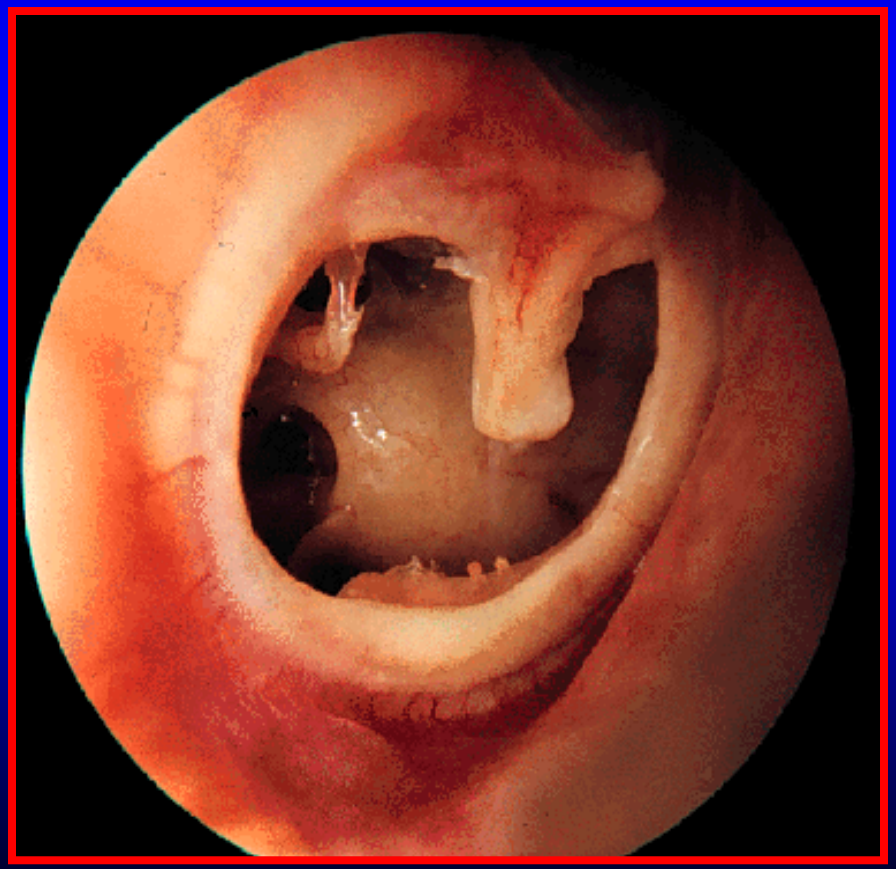
Causes Injuries to Gas-Filled Organs

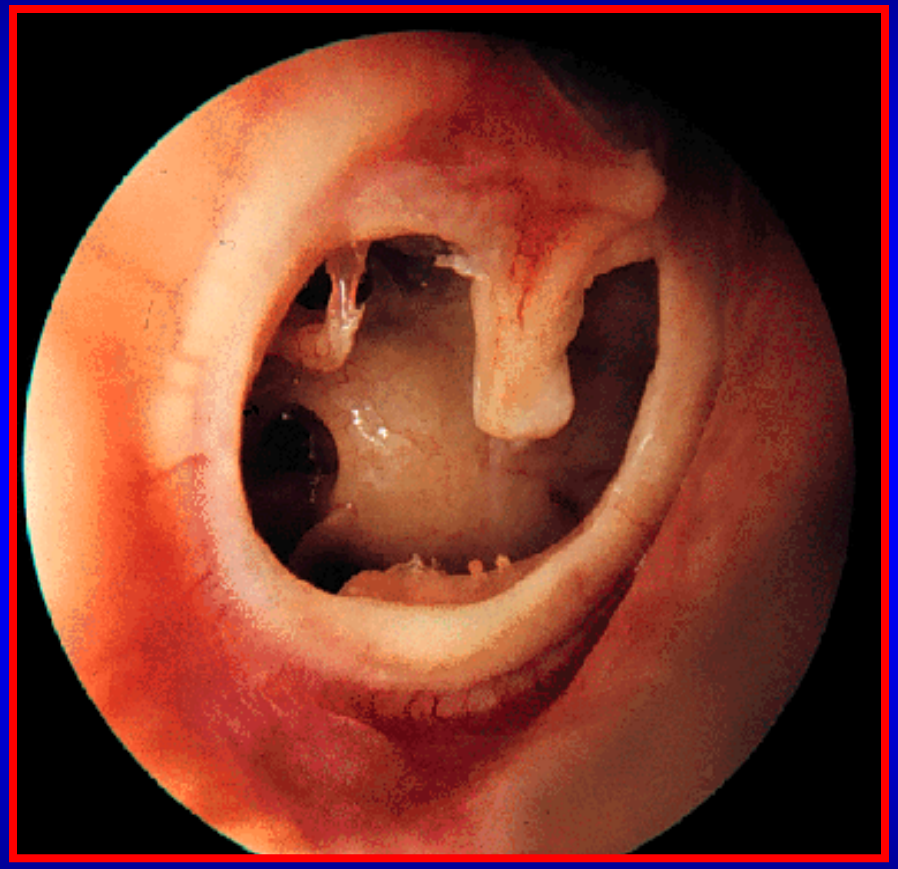
- EARS
- LUNGS
- GI TRACT

…Also Causes Brain Injuries Without Physical Signs **(concussion)**

PBI: *Auditory System*

- **Ruptured Tympanic Membranes**
  (most common ear injury)



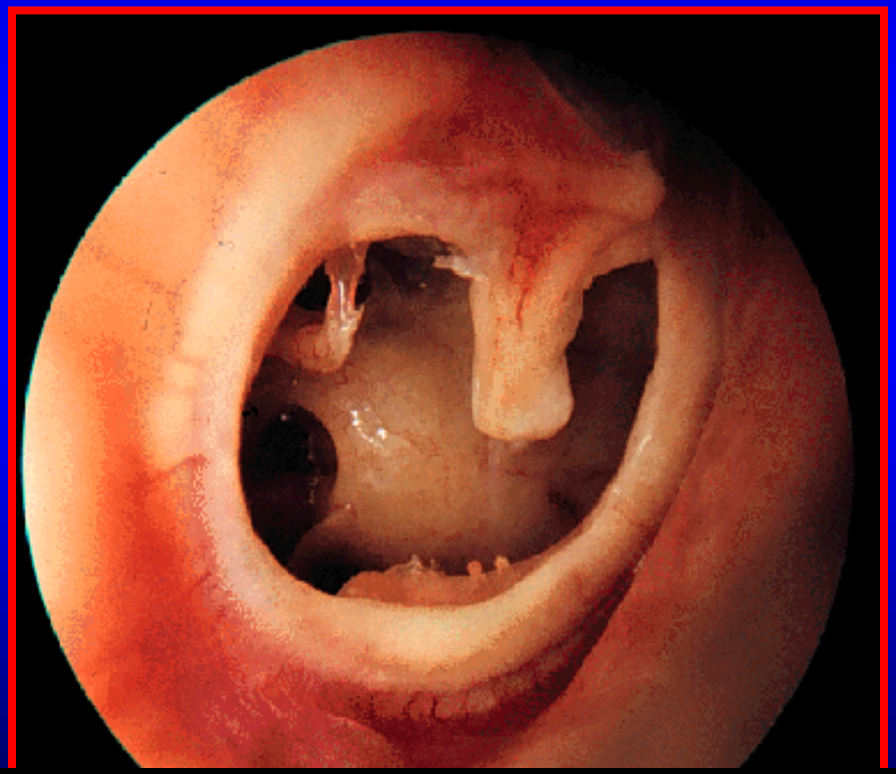


PBI: *Auditory System*

- **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 Fistulae *(air emboli)***

PBI: *Lungs*

"Blast lung"

- Second most susceptible organ
- Usually symptomatic immediately,
  can be delayed up to 48 hours
- Direct consequence of blast wav
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)**

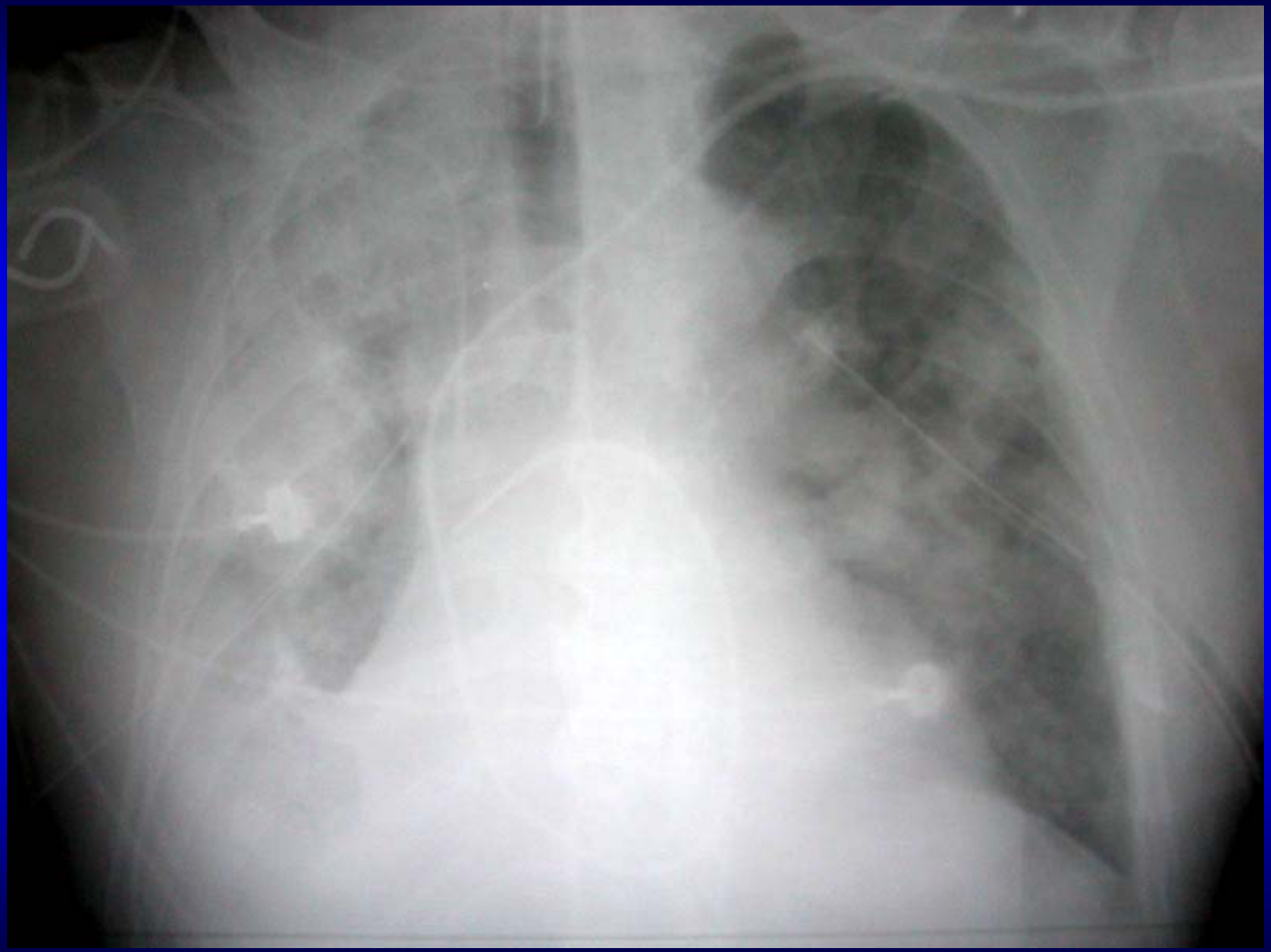
PBI: *Lungs*

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



WWII Blast Lung Injury

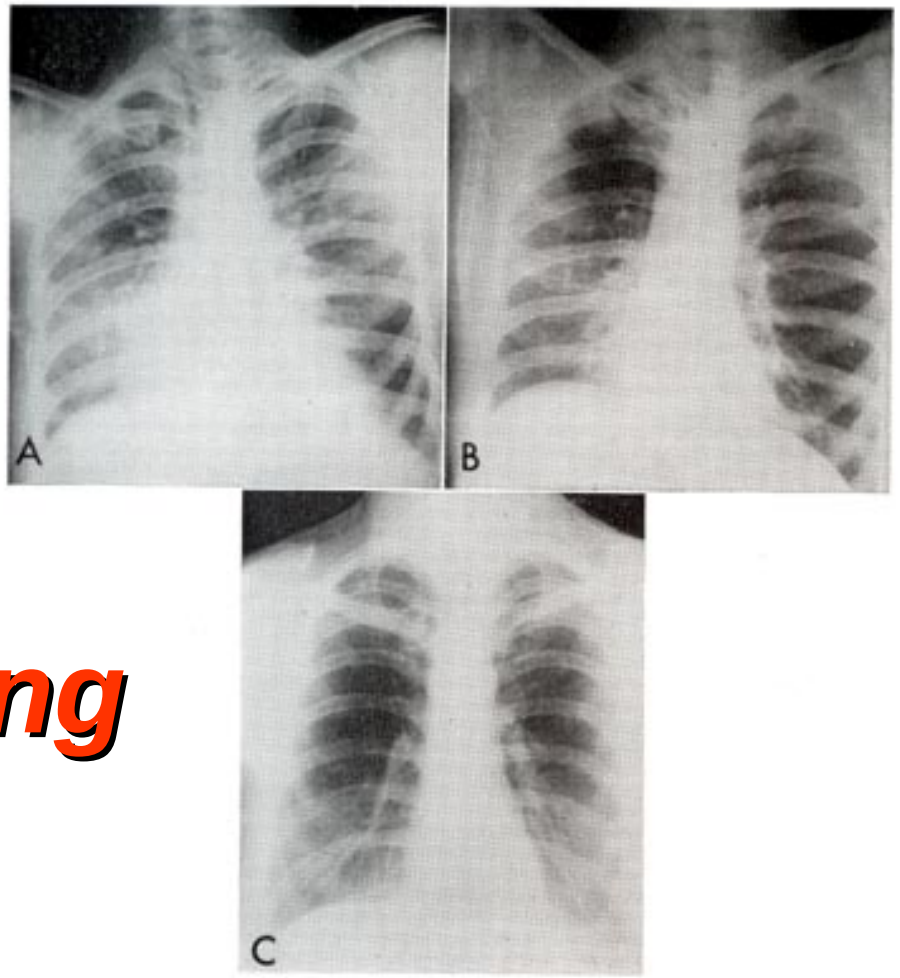


FIGURE 204 (case 5).—Serial roentgenograms in blast injury. A. Posteroanterior roentgenogram, 11 November 1943, 24 hours after injury, showing diffuse bilateral haziness and infiltration indicative of petechial pulmonary hemorrhage and edema. B. Posteroanterior roentgenogram, 17 November 1943, showing 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)

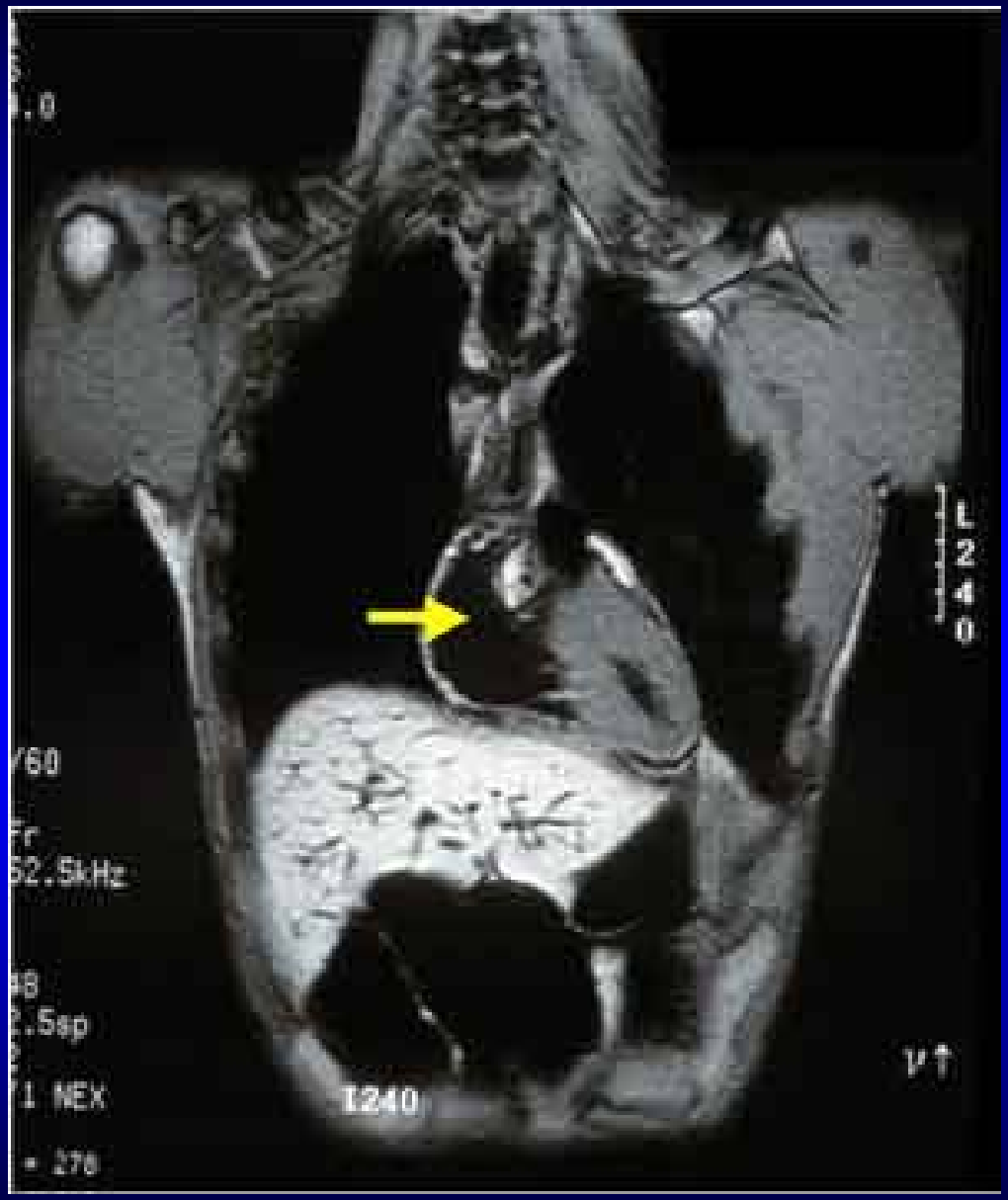
PBI: *Lungs*

Systemic Air Embolism

- Vascular Obstruction…

…referable to location of occlusion:

- Chest pain (coronary symptoms)
- Focal Neurological Deficit
- Blindness
- Tongue Blanching
- Skin changes


L
2
4
0
I240

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 *(more air)* Involved > Small Bowel**
- **Acute or Delayed Rupture Seen**
  - **Due to stretching & ischemic bowel wall weakening**
  - **Shear Forces May Tear Mesentery**

Still…

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

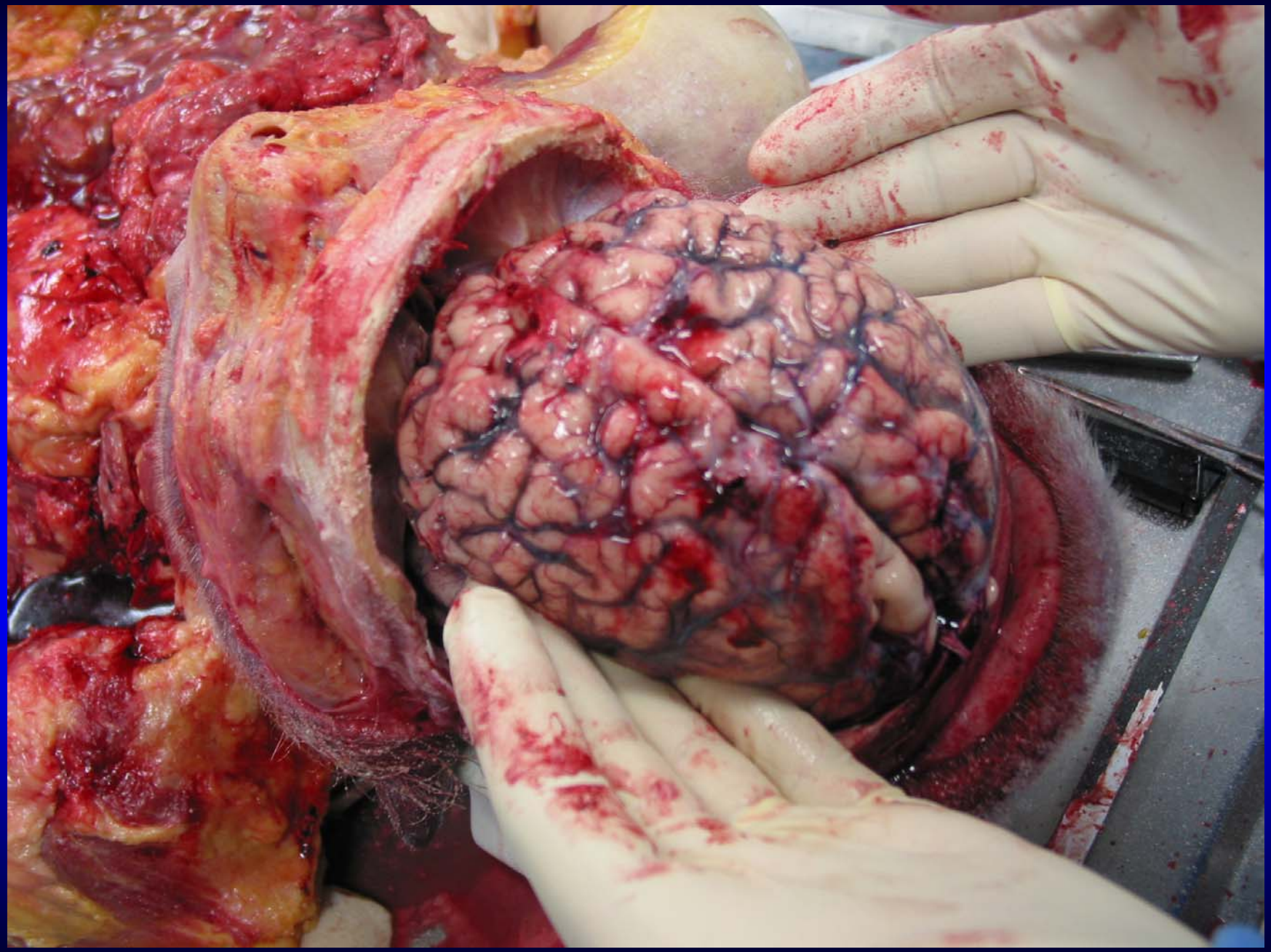
Intestinal Mucosal Edema

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

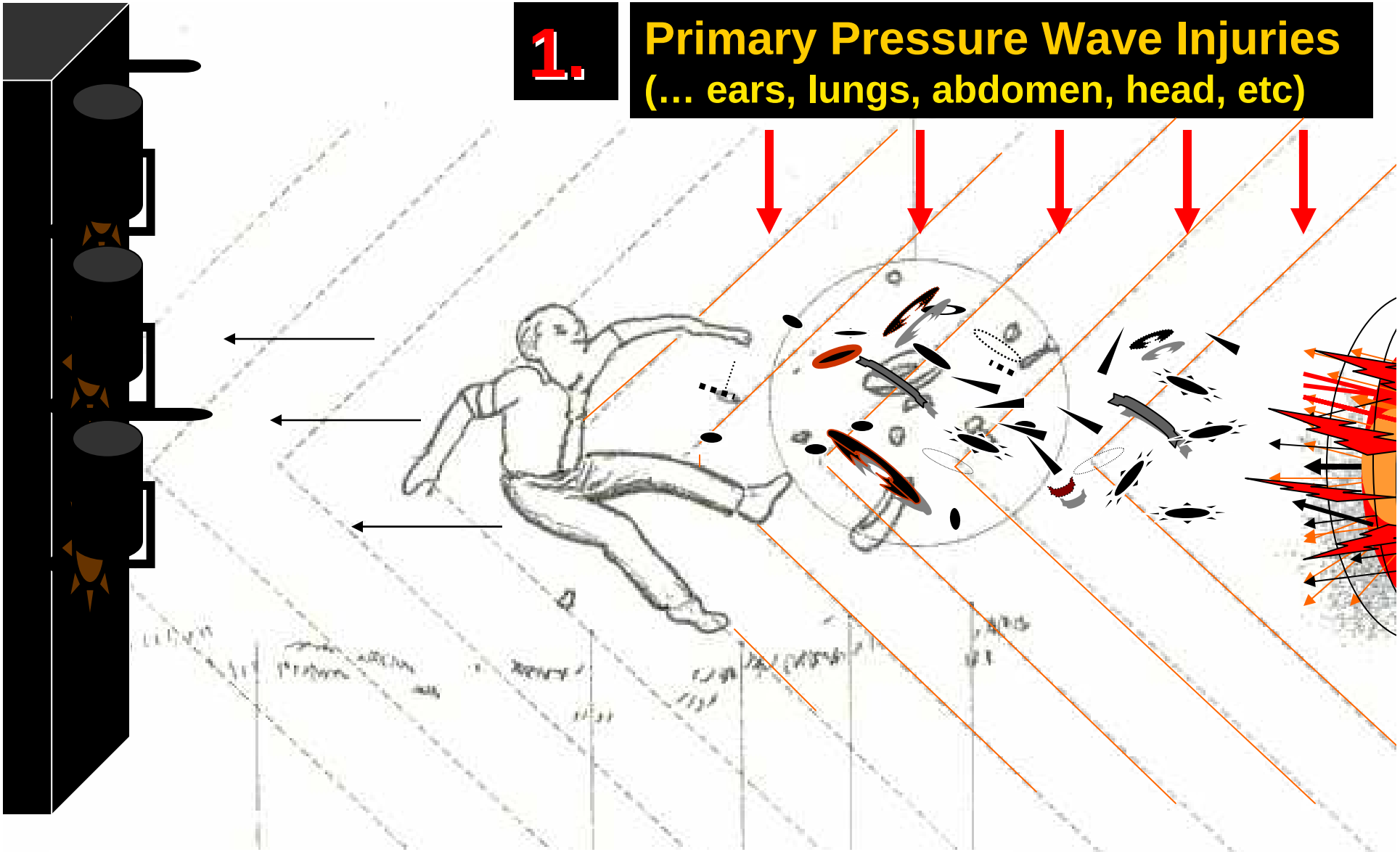
Penetrating & Blunt Injuries:

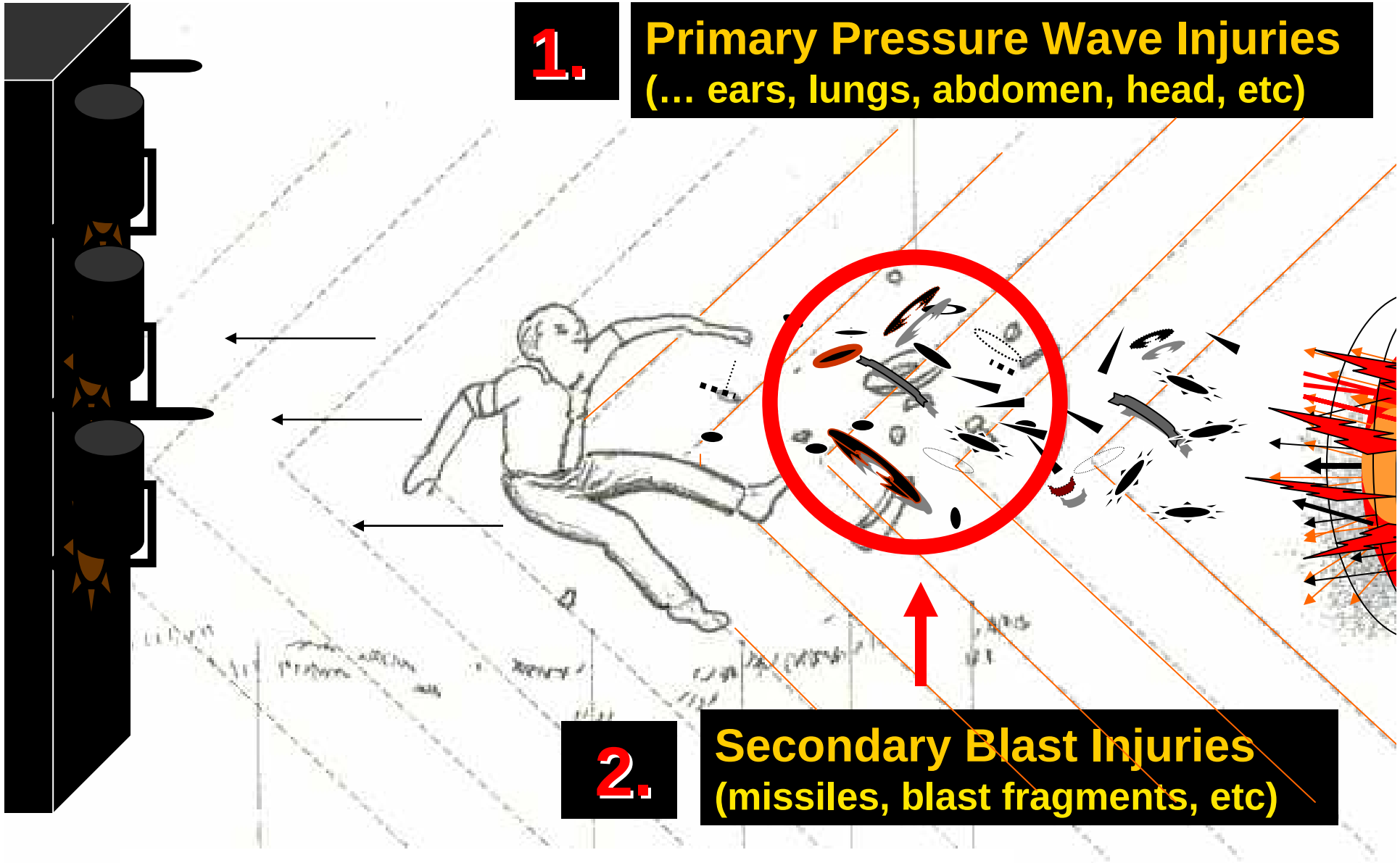
Tertiary Blast Injury

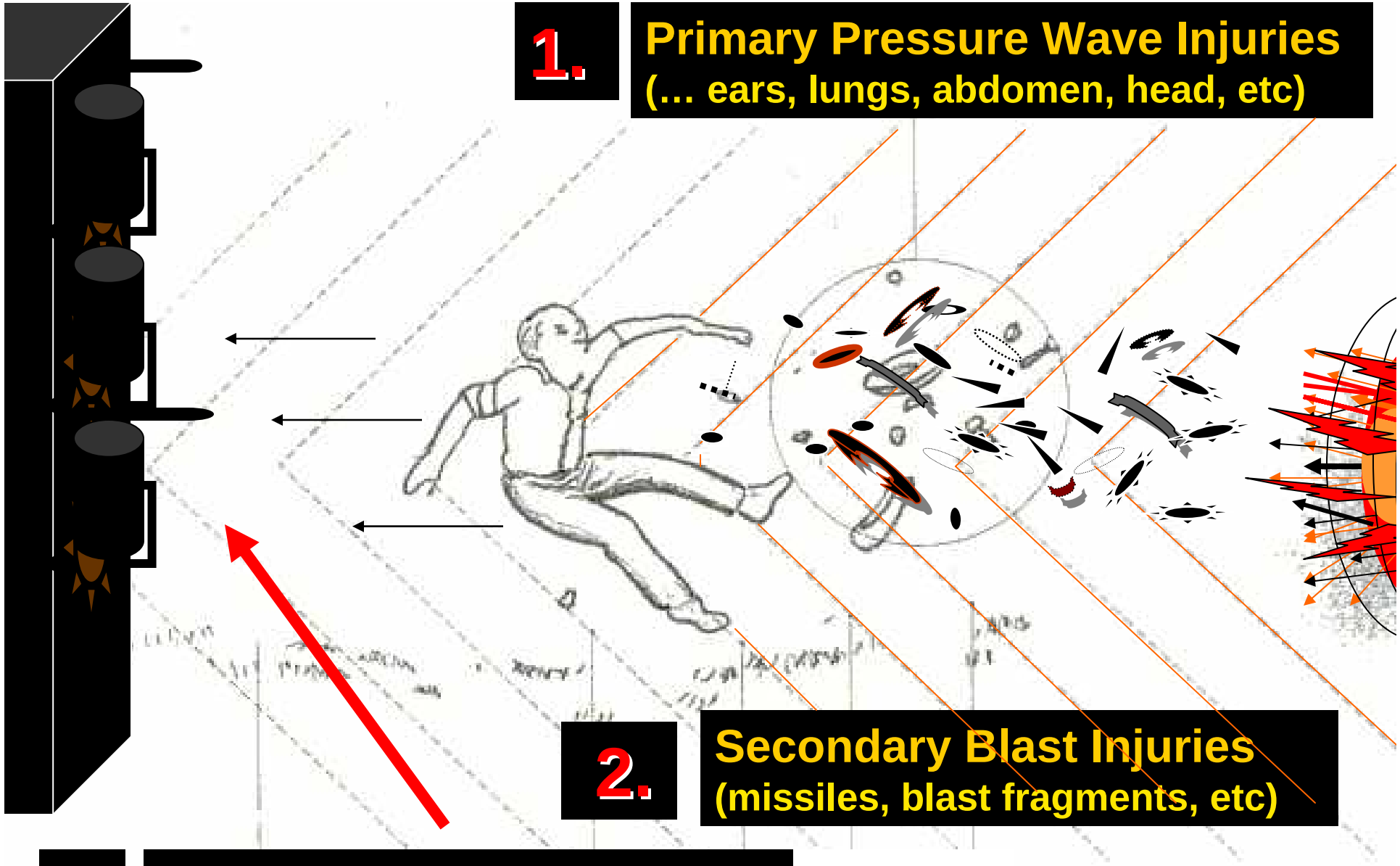
- Patient Becomes a Missile
- Impaled or Hits a Hard Surface
- Can Result in Penetrating and Blunt Injuries

SO TO SUMMARIZE BLAST INJURIES…

1. Primary Pressure Wave Injuries
(… ears, lungs, abdomen, head, etc)




1.
Primary Pressure Wave Injuries
(… ears, lungs, abdomen, head, etc)
2.
Secondary Blast Injuries
(missiles, blast fragments, etc)


1.
Primary Pressure Wave Injuries
(… ears, lungs, abdomen, head, etc)
2.
Secondary Blast Injuries
(missiles, blast fragments, etc)
3.
Tertiary Blast Injuries
(from impalement or landing on
hard surface, sharp objects, 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:

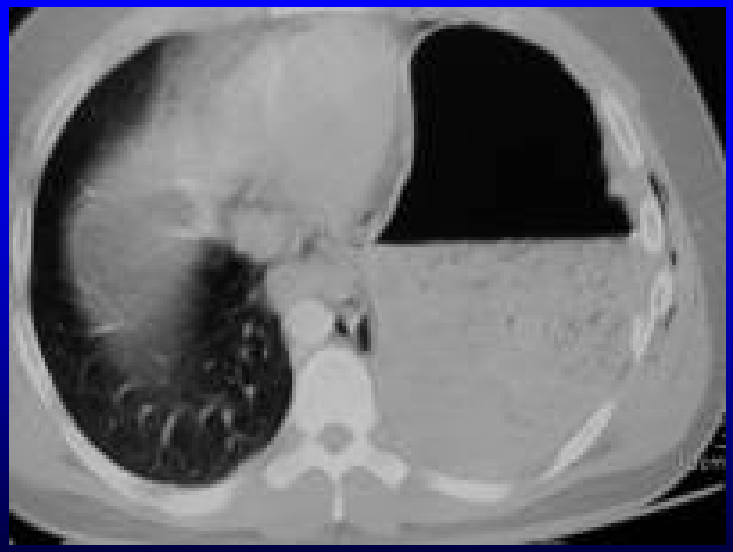
- **Traumatic Asphyxia**
- **Crush Injuries**
- **Compartment Syndrome**

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 !**

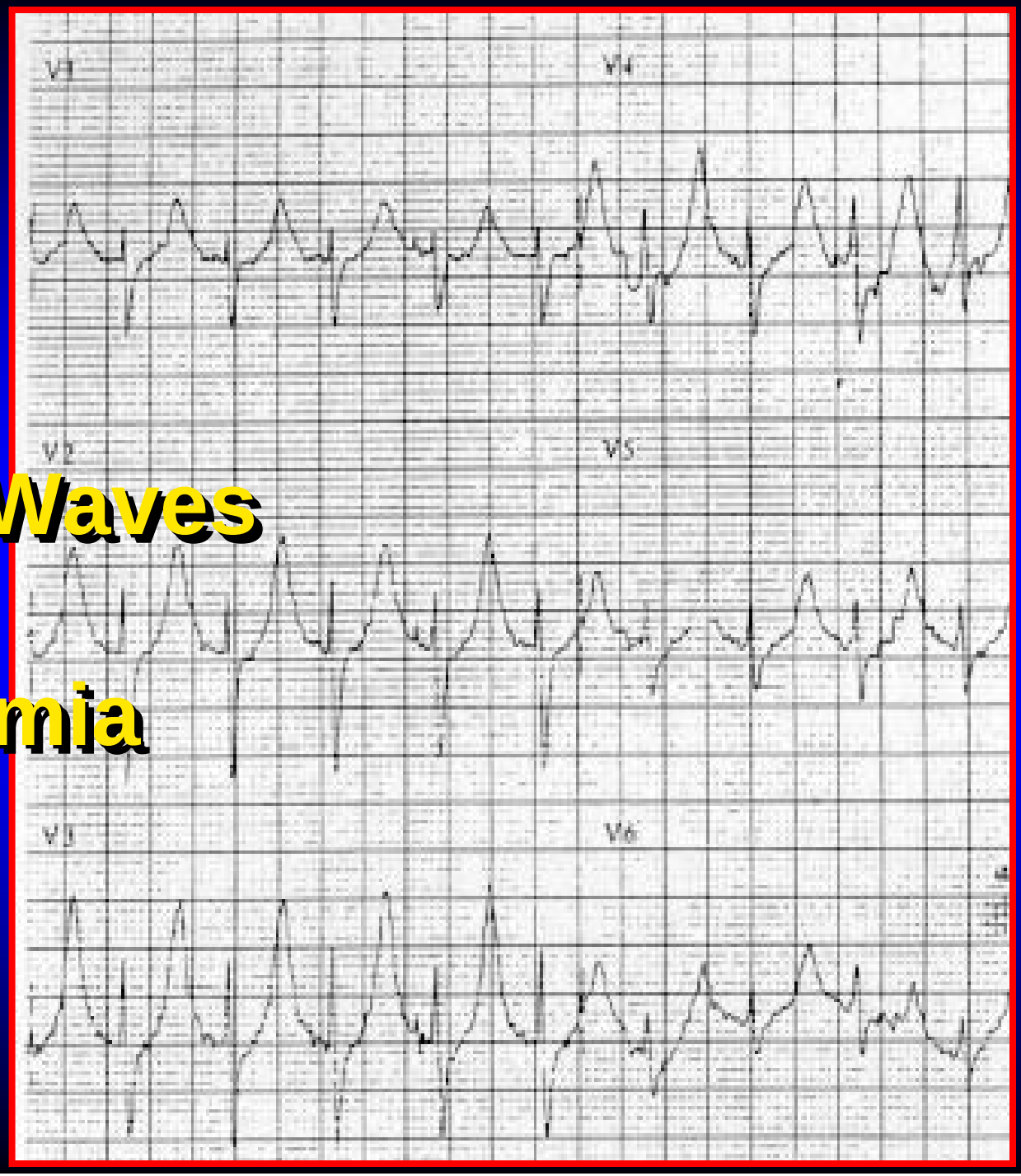
  …Dramatic 3rd Spacing (“hypovolemia”) & Neg. Inotropic effects = Profound Shock

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

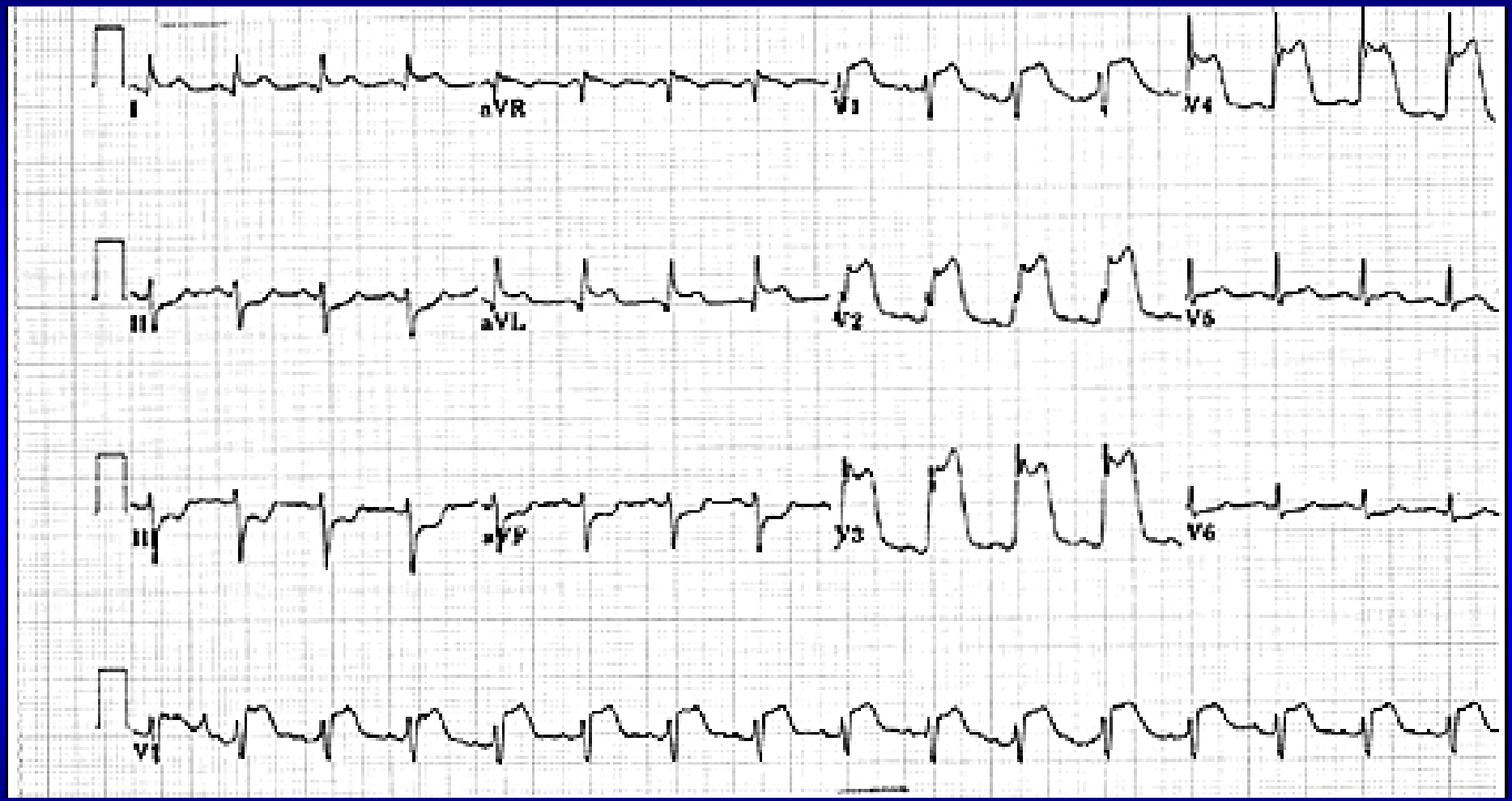
Mechanisms of Injury

EXACERBATION OF EXISTING MEDICAL CONDITIONS

Mechanisms of Injury
Worsened Medical Conditions

- Angina
- Asthma
- COPD
- Hypertension

…and other chronic health problems


I
aVR
V1
V4
II
aVL
V2
V5
II
aVF
V3
V6
V1

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

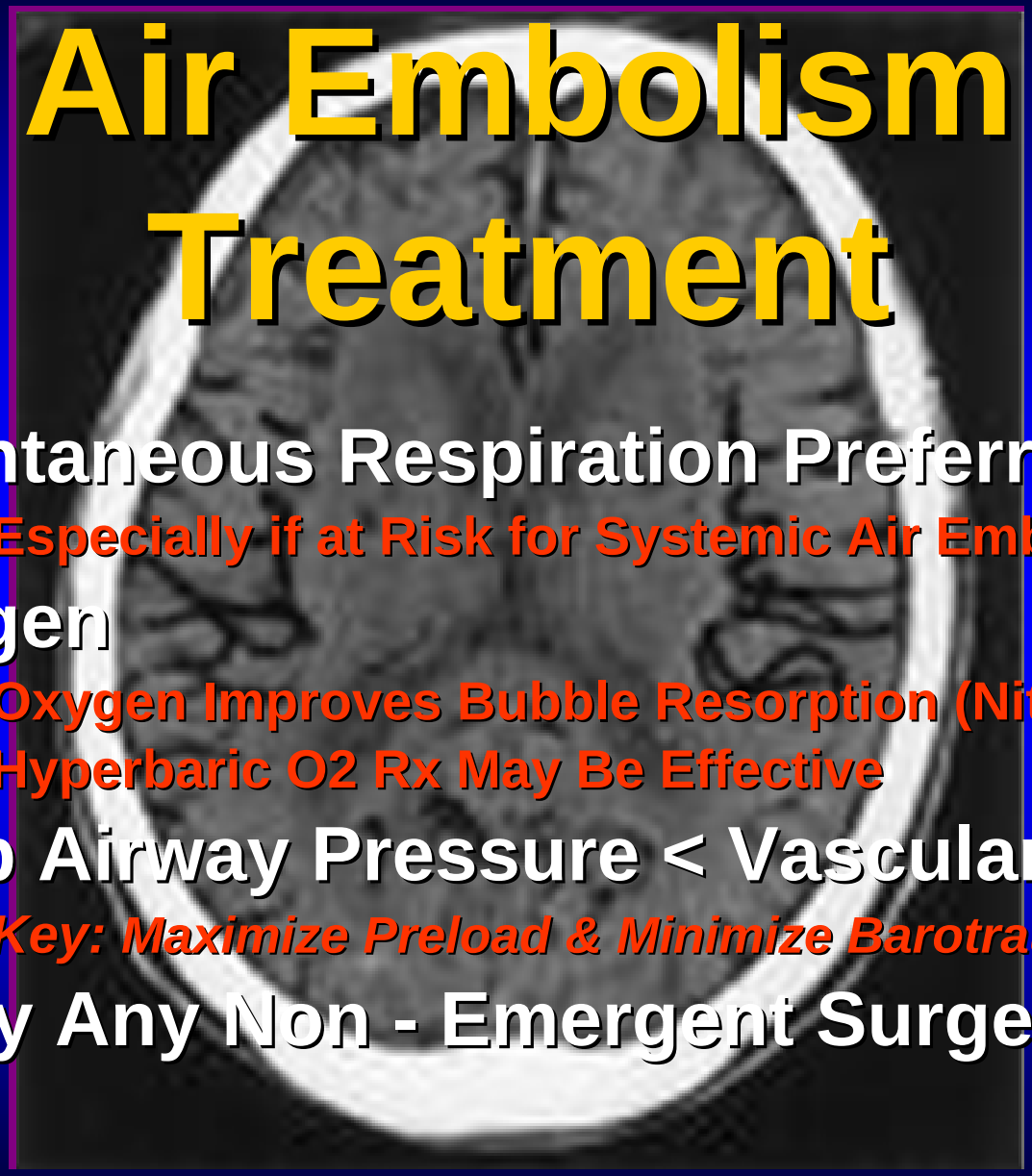
- Support Oxygenation
  - 100% Supplemental O_2
- ATLS Chest Trauma Guidelines
- If Primary Blast Injury Suspected:
  - Minimize Pt. Activity
  - Spontaneous Breathing Preferred
  - Avoid Overzealous Assisted Ventilation
- Consider Prophylactic Chest Tubes Prior to PPV and/or Air Transport

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

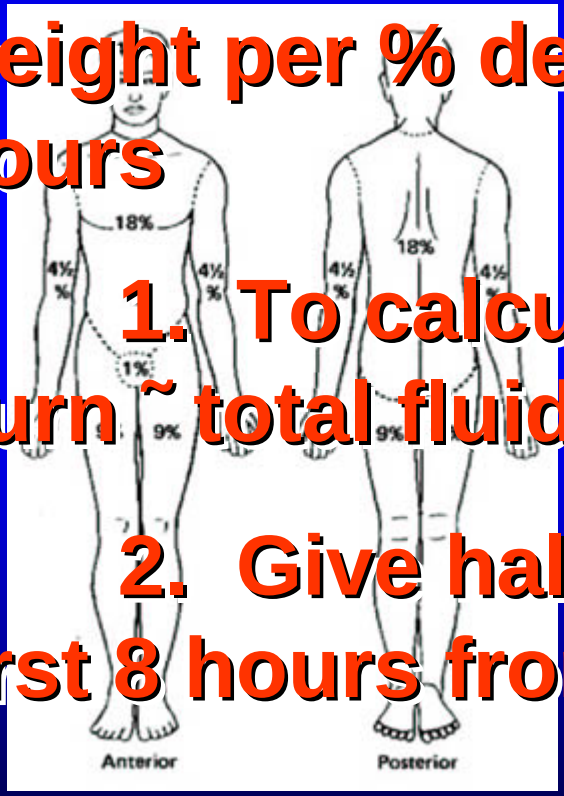
- Anticipate Hypovolemia and Heat Loss
- Dress the Burns – Clean, Dry Dressing
- Evacuate to Appropriate Facility

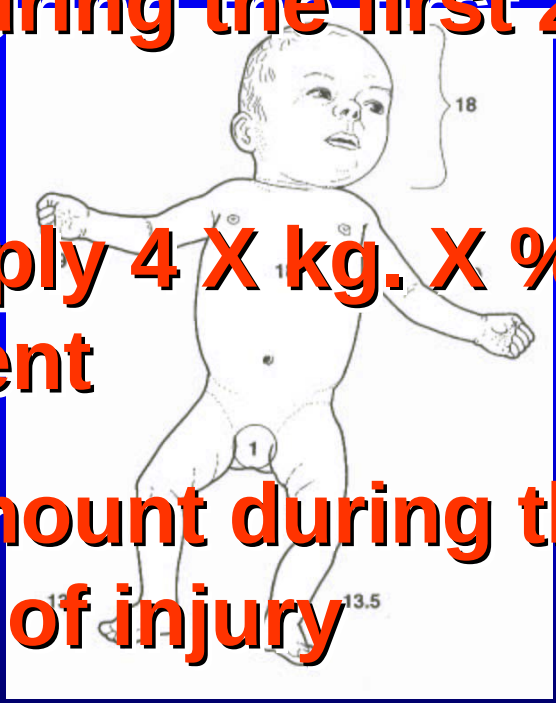
Treatment of Burns

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

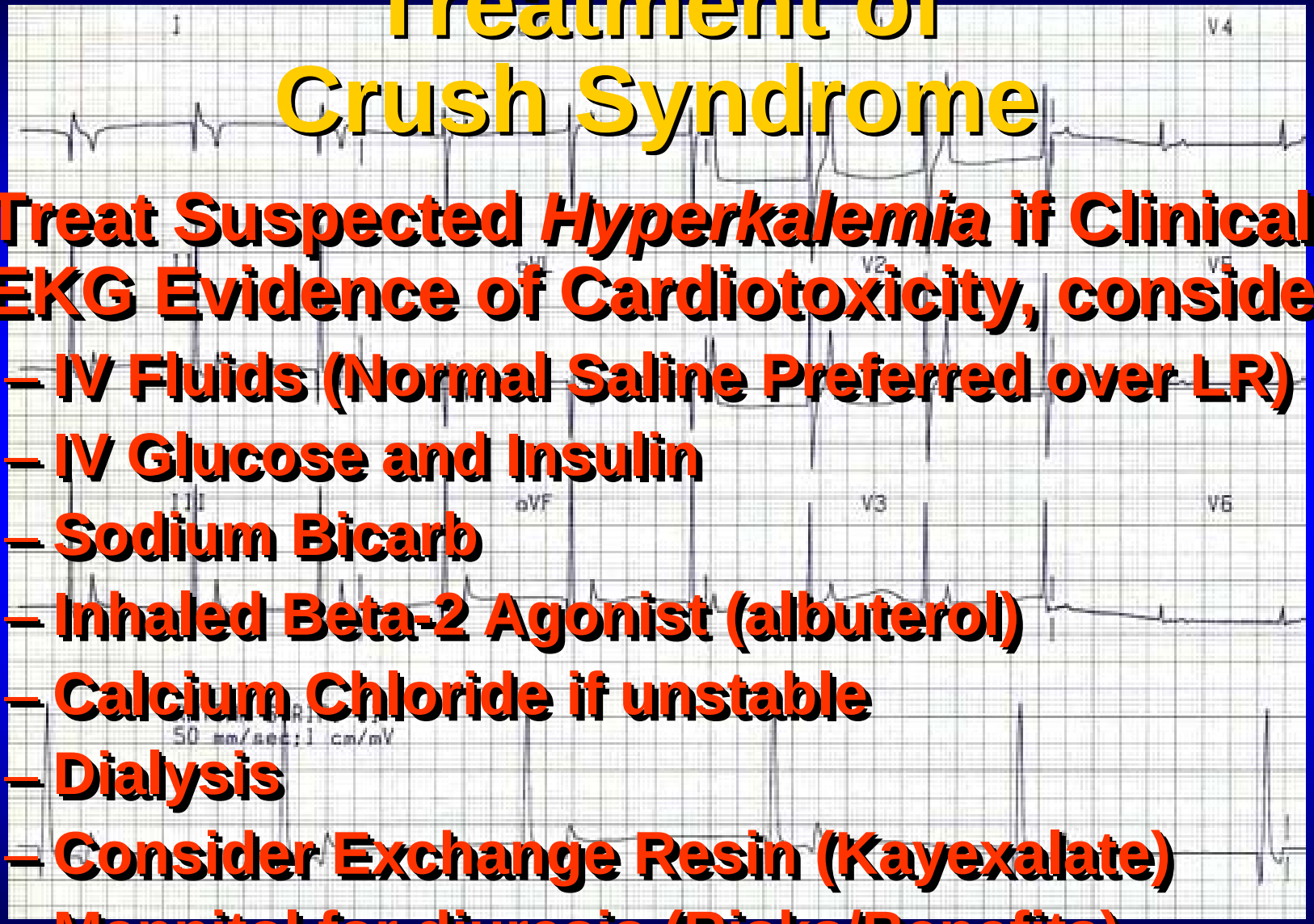




Treatment of Traumatic Asphyxia

- 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

↓

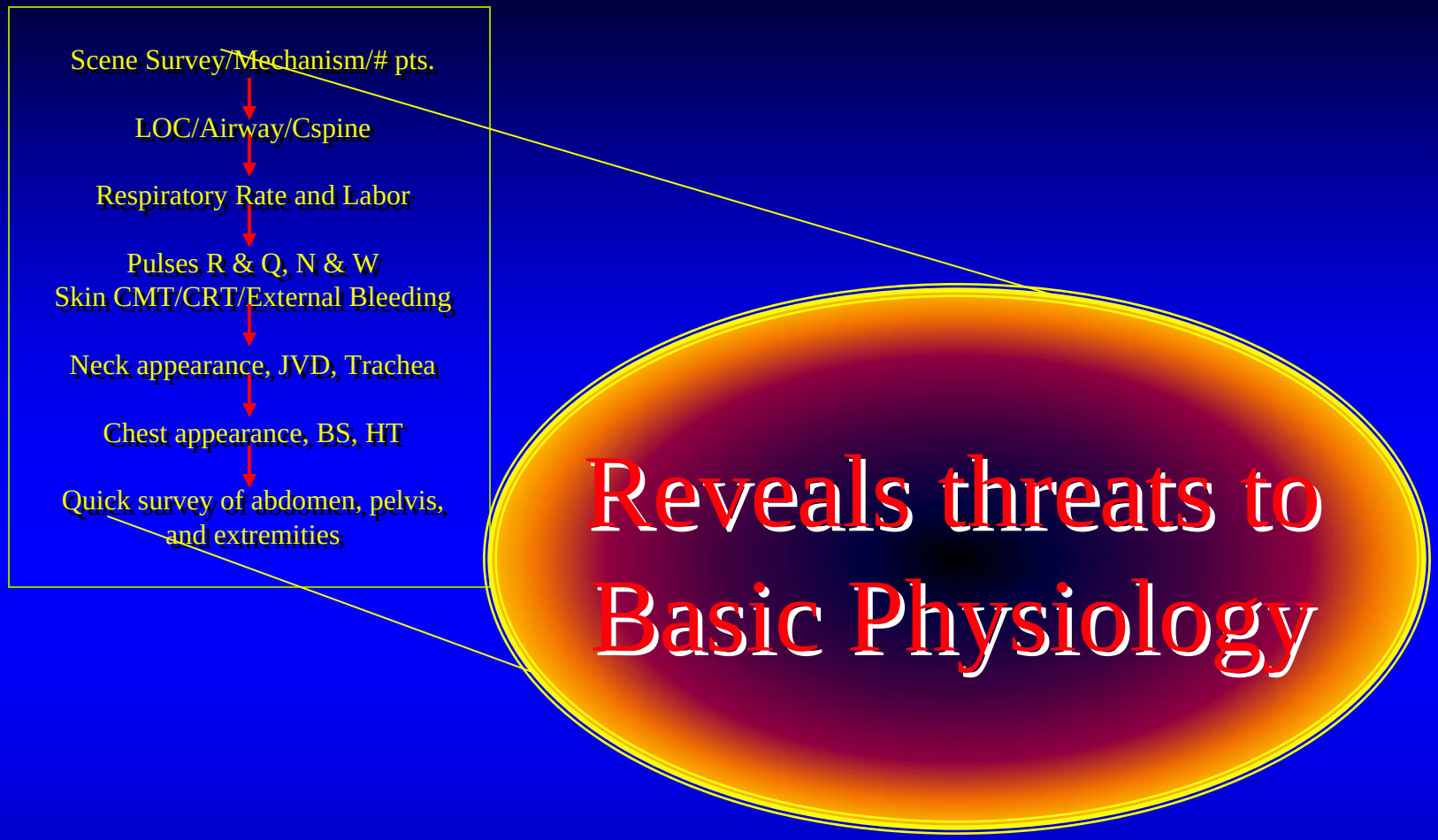
Neck appearance, JVD, Trachea

↓

Chest appearance, BS, HT

↓

Quick survey of abdomen, pelvis, extremities, and back



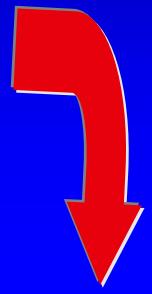
. . .the vital elements of the Primary Survey

Shock

Blood pressure =

Cardiac output x
Peripheral resistance

Blood pressure =



Pump x fluids x 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

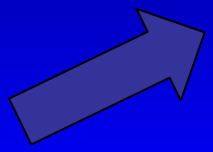
What is the problem with shock?

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

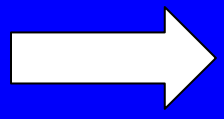
Heart: Cardiogenic, or mechanical
Volume: Low volume
Vasodilatory: High space

Shock



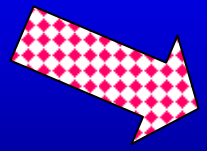
Cardiogenic

- 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

SFAR

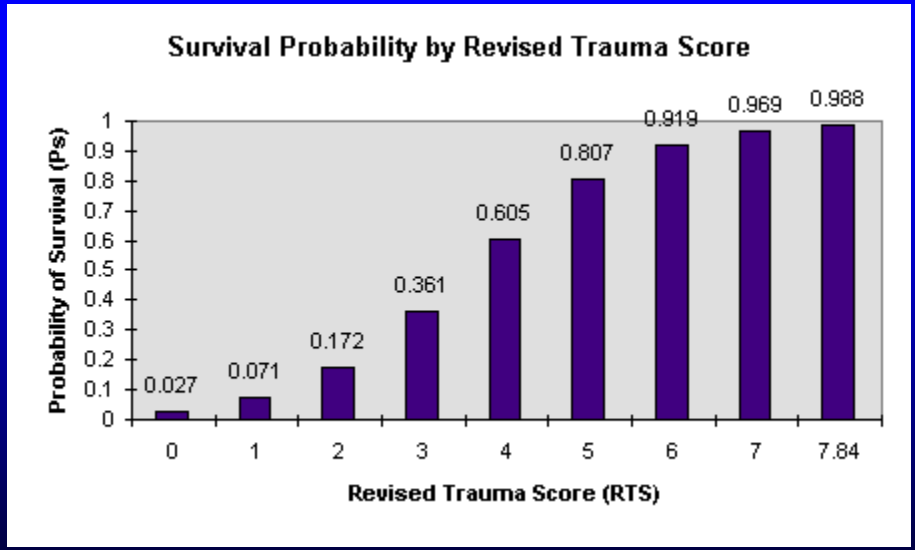
ISS - RTS - TRISS

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

Variables	Severity level (help)	Points
Head and neck		0
Face		0
Chest		0
Abdomen, pelvic contents		0
Extremity, pelvic girdle		0
External		0
ISS = 0		
Respiratory rate (per min)		0
Systolic blood pressure (mmHg)		0
Glasgow coma scale (help)		0
RTS = 0		
Age (Pediatric cases (Ages < 15) use the blunt model for both blunt and penetrating mechanisms of injury.)		0
Predicted death rate (blunt) TRISS =	Clear	Predicted death rate (penetrating) TRISS =
ISS = Sum ((three most weighted region injury)^2). ISS equals 75 for any patient with an AIS 6 injury. RTS = Sum ((resp.rate.points)*0.2908; (sbp.points)*0.7326; (Glasgow.points)*0.9368)	TRISS (blunt): Logit =-0.4499 + RTS*0.8085 + ISS*-0.0835 + (age.points)*-1.7430 Predicted death rate = $1/(1 + e^{Logit})$	TRISS (penetrating): Logit =-2.5355 + RTS*0.9934 + ISS*-0.0651 + (age.points)*-1.1360 Predicted death rate = $1/(1 + e^{Logit})$

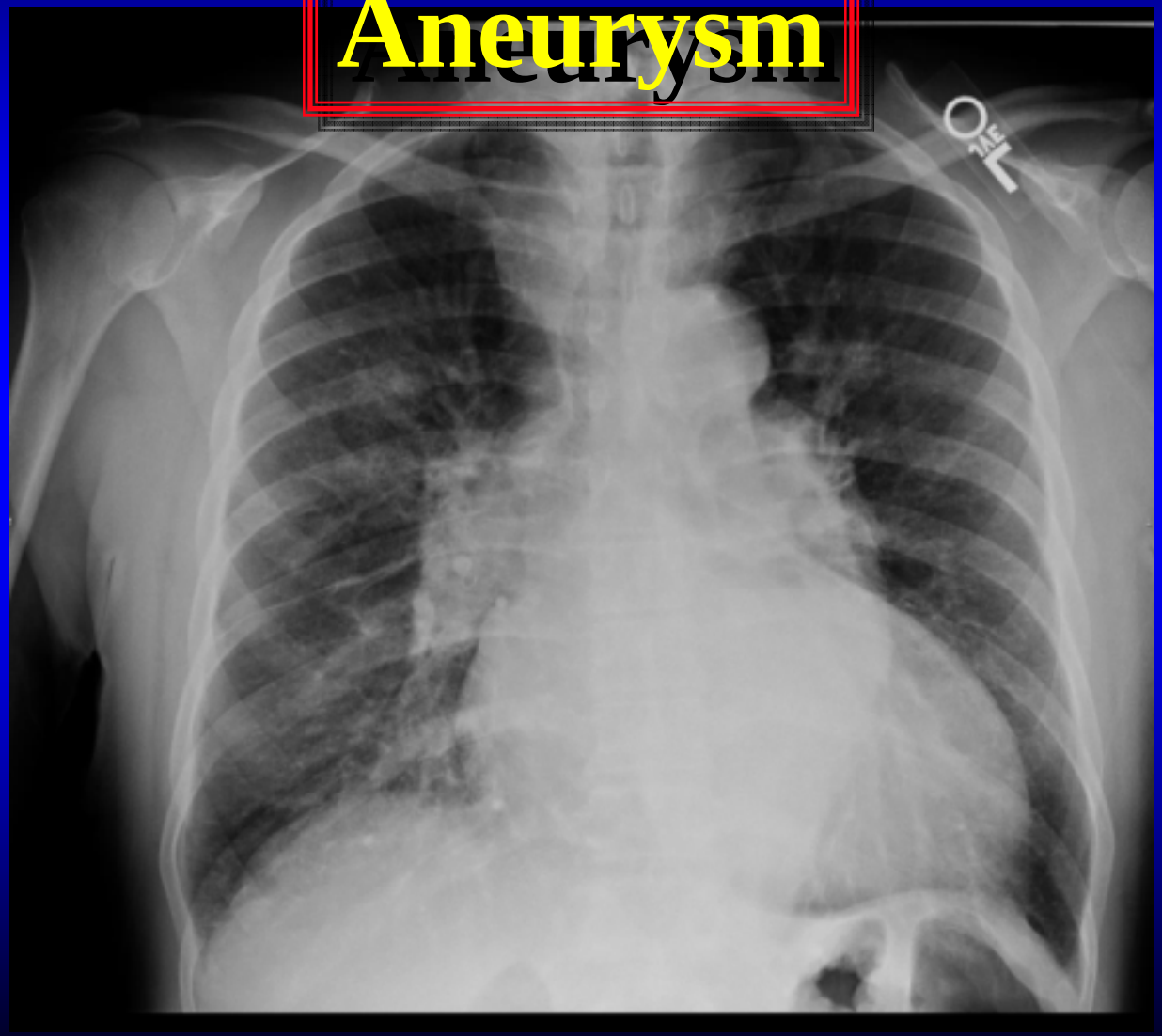
Revised Trauma Score

Glasgow Coma Scale (GCS)	Systolic Blood Pressure (SBP)	Respiratory Rate (RR)	Coded Value
13-15	>89	10-29	**4**
9-12	76-89	>29	**3**
6-8	50-75	6-9	**2**
4-5	1-49	1-5	**1**
3	0	0	**0**



Penetrating Abdominal and Lower Thoracic Trauma

Thoracic Aneurysm



Shock Management

In the setting of uncontrolled hemorrhage, low volume resuscitation seems appropriate, maintaining peripheral pulses

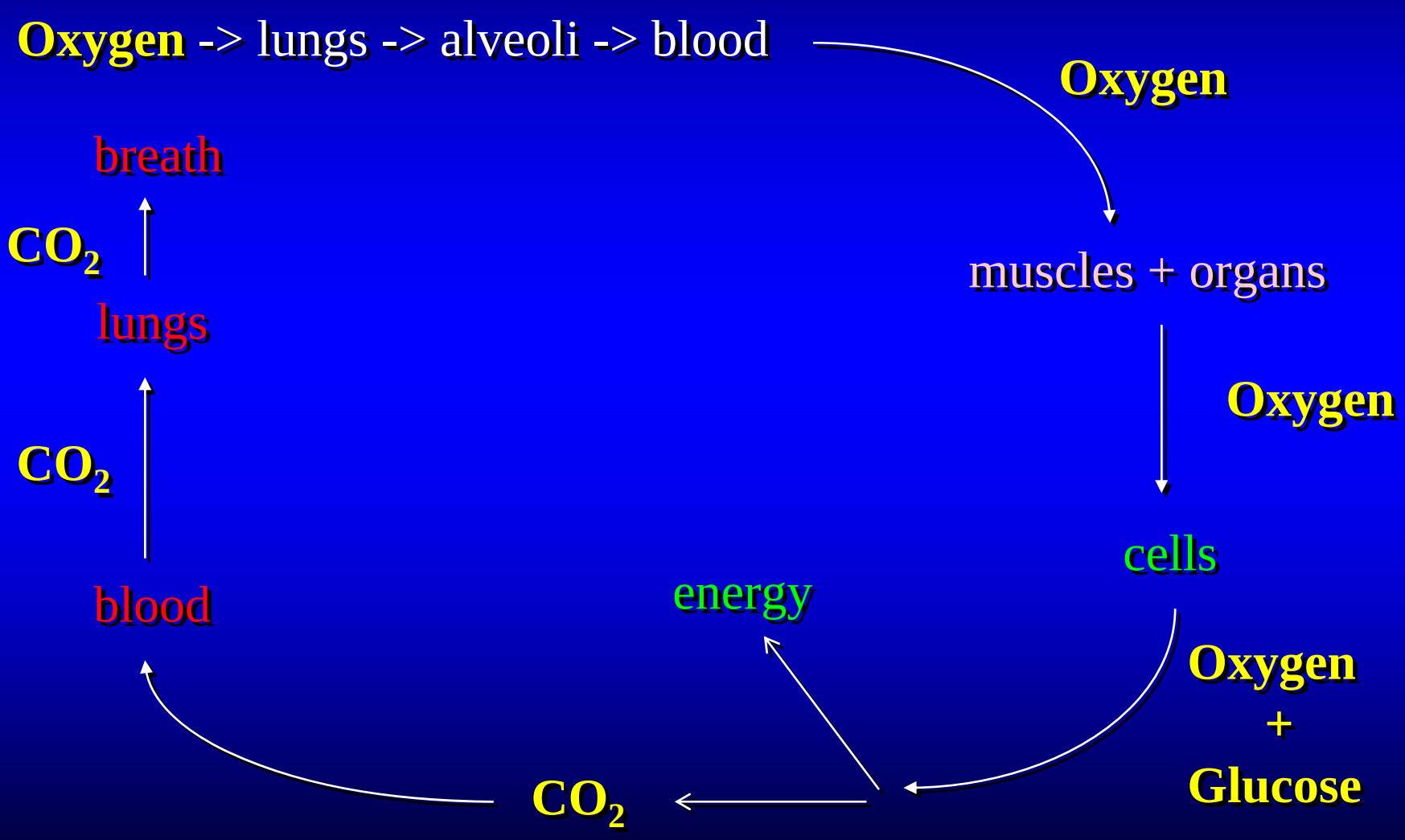
Post Cardiac Arrest

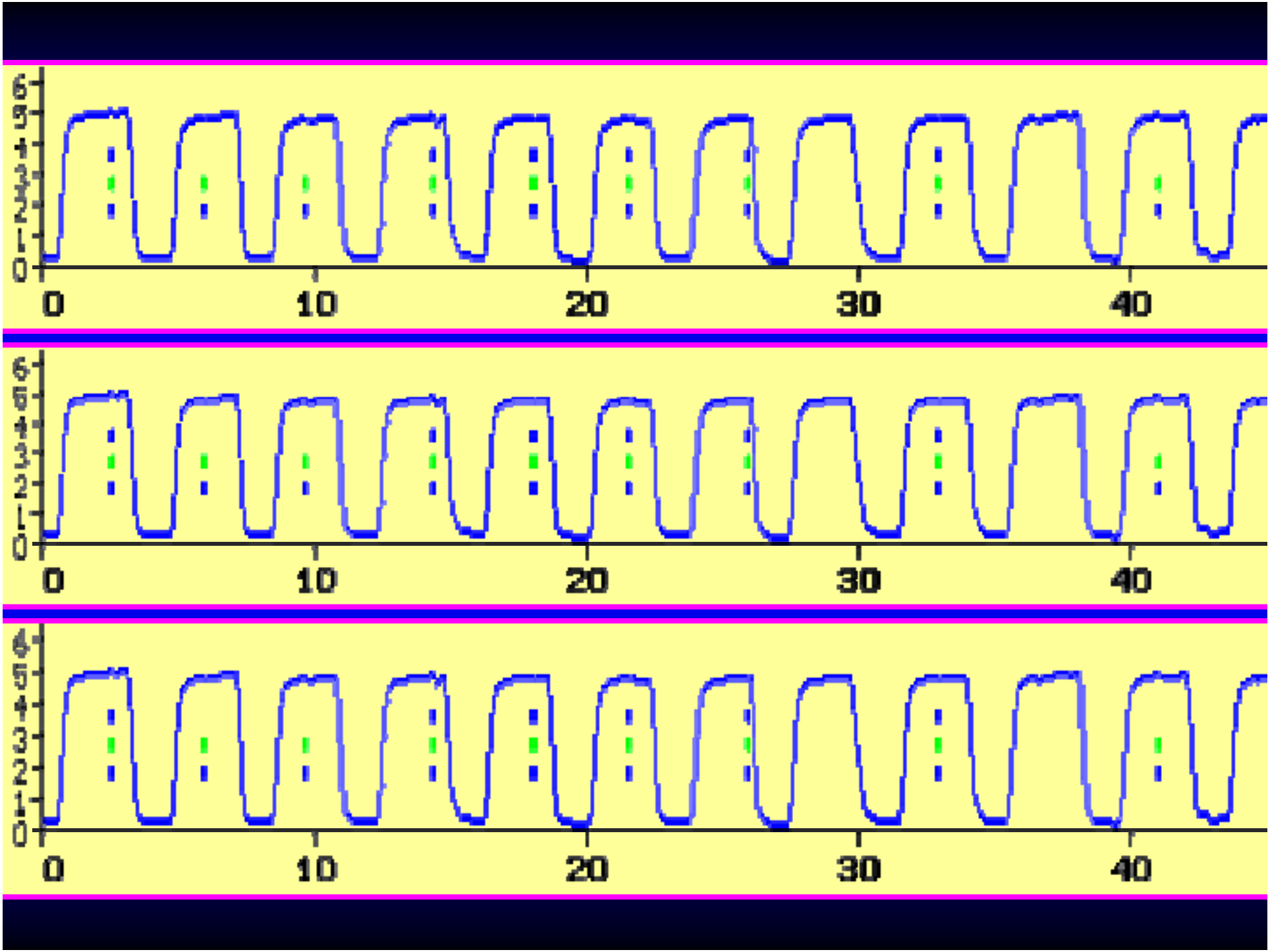
The era of induced hypothermia for brain preservation post cardiac arrest is here, and you and your teams should be exploring this…

…beginning in the EMS area!


Ventilation
and Critical Care

Physiology


Oxygen -> lungs -> alveoli -> blood
Oxygen
breath
CO_2
muscles + organs
lungs
Oxygen
CO_2
cells
energy
blood
Oxygen
+
Glucose
CO_2


0
1
2
3
4
5
6
0
10
20
30
40

Need to Ventilate

- **CO_2 Production**

  (O_2 Consumption & Venous Return)

- **Airway Dead Space**

  (wasted ventilation)

Speed of Ventilation

- **CO_2 Production**

  (O_2 Consumption & Venous Return)

- **Airway Dead Space**

  (wasted ventilation)

Generally speaking:

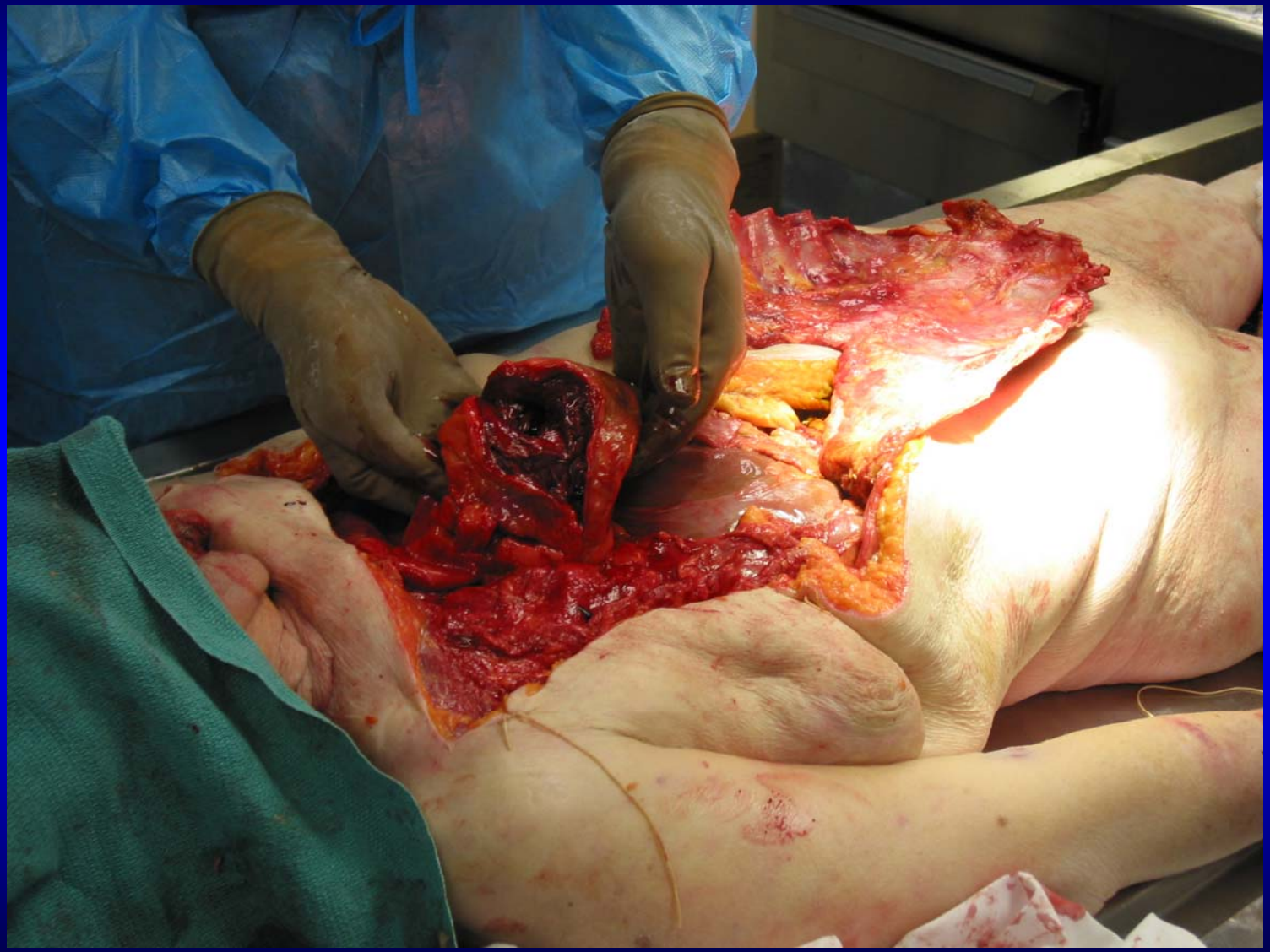
The patient in circulatory collapse suffers greatly from positive pressure ventilation

The negative pressure inside the thorax “pulls” blood back from the positive pressure areas.

Positive pressure

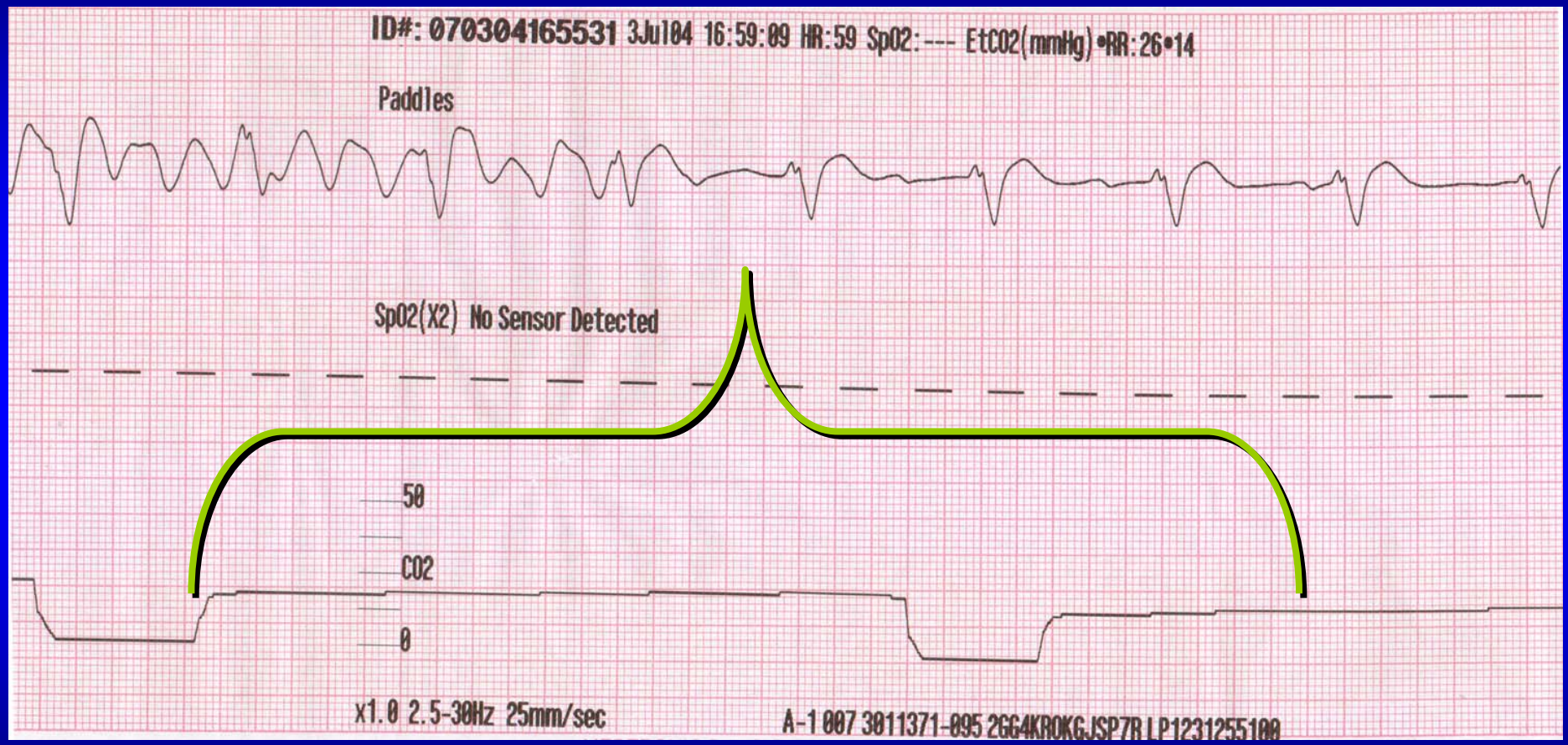
Negative pressure

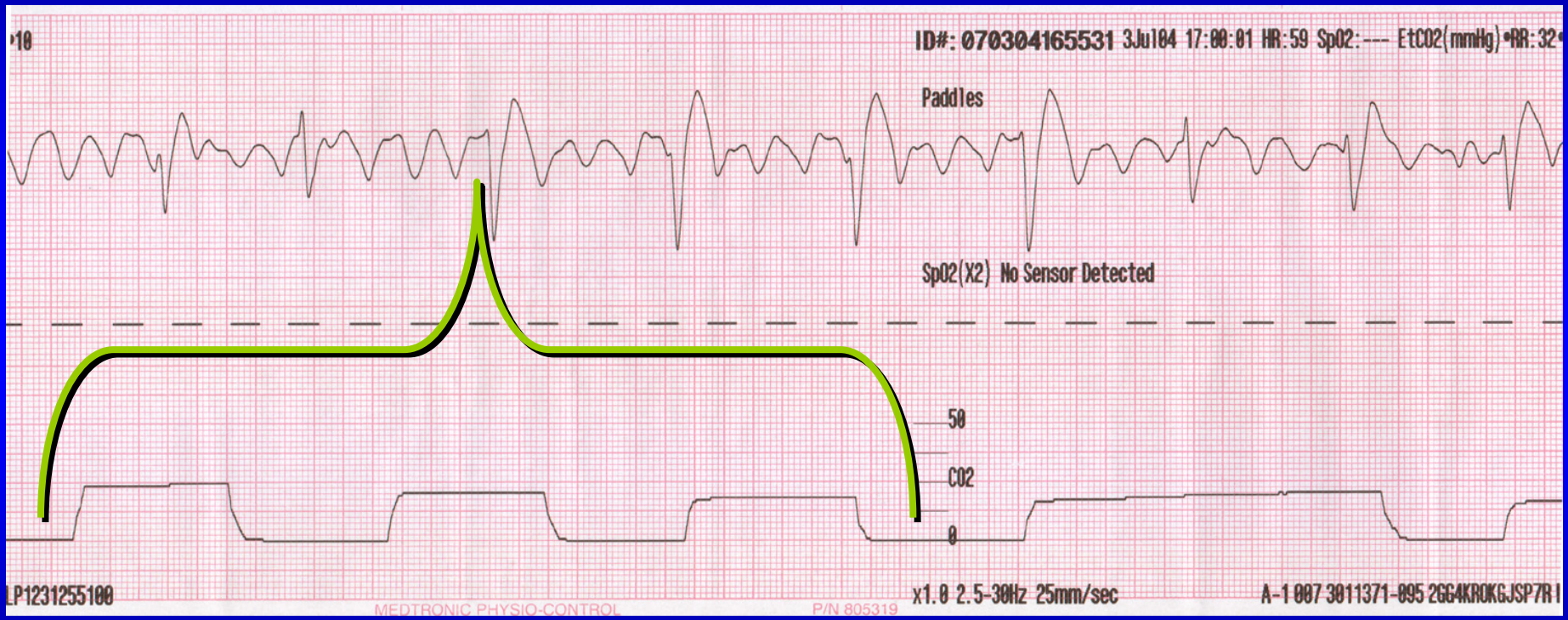
Positive pressure

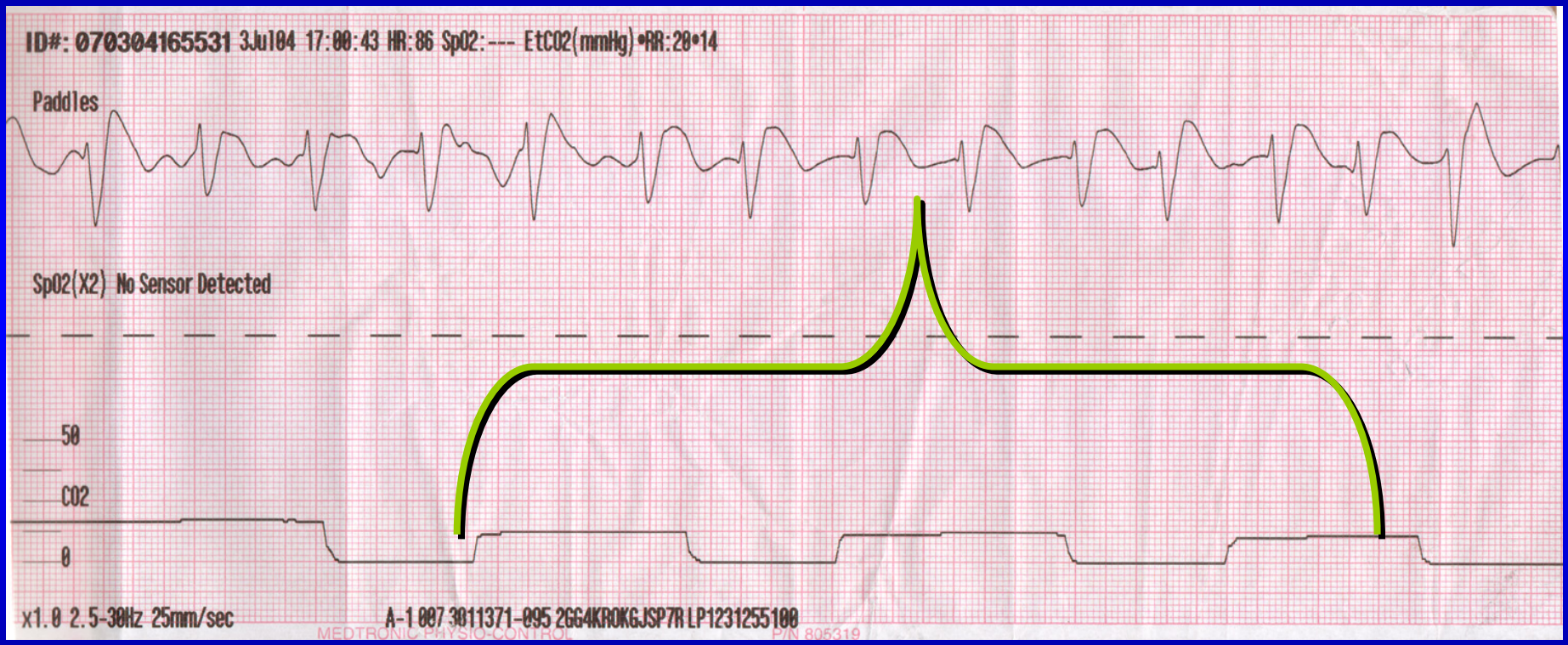


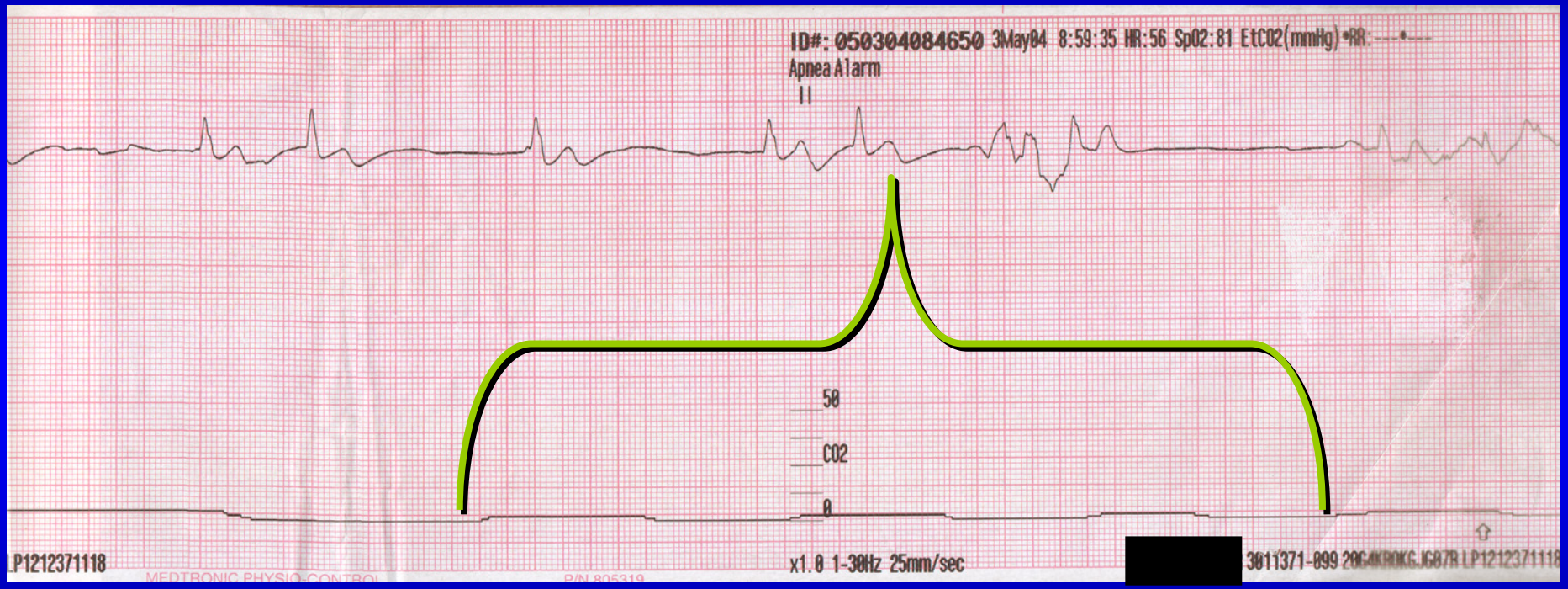
Positive Pressure in the Thorax decreases Venous Return!!

Breathing the patient too fast INCREASES pressure inside the chest!


ID#: 070304165531 3Jul04 16:59:09 HR:59 SpO2:--- EtCO2(mmHg) •RR:26•14
Paddles
SpO2(X2) No Sensor Detected
50
CO2
0
x1.0 2.5-30Hz 25mm/sec
A-1 007 3011371-095 2GG4KROKGJSP7R LP1231255100


10
ID#: 070304165531 3Jul04 17:00:01 HR:59 SpO2:--- EtCO2(mmHg) RR:32
Paddles
SpO2(X2) No Sensor Detected
50
CO2
0
LP1231255100
x1.0 2.5-30Hz 25mm/sec
A-1 007 3011371-095 2GG4KROKGJSP7R1
MEDTRONIC PHYSIO-CONTROL
P/N 805319

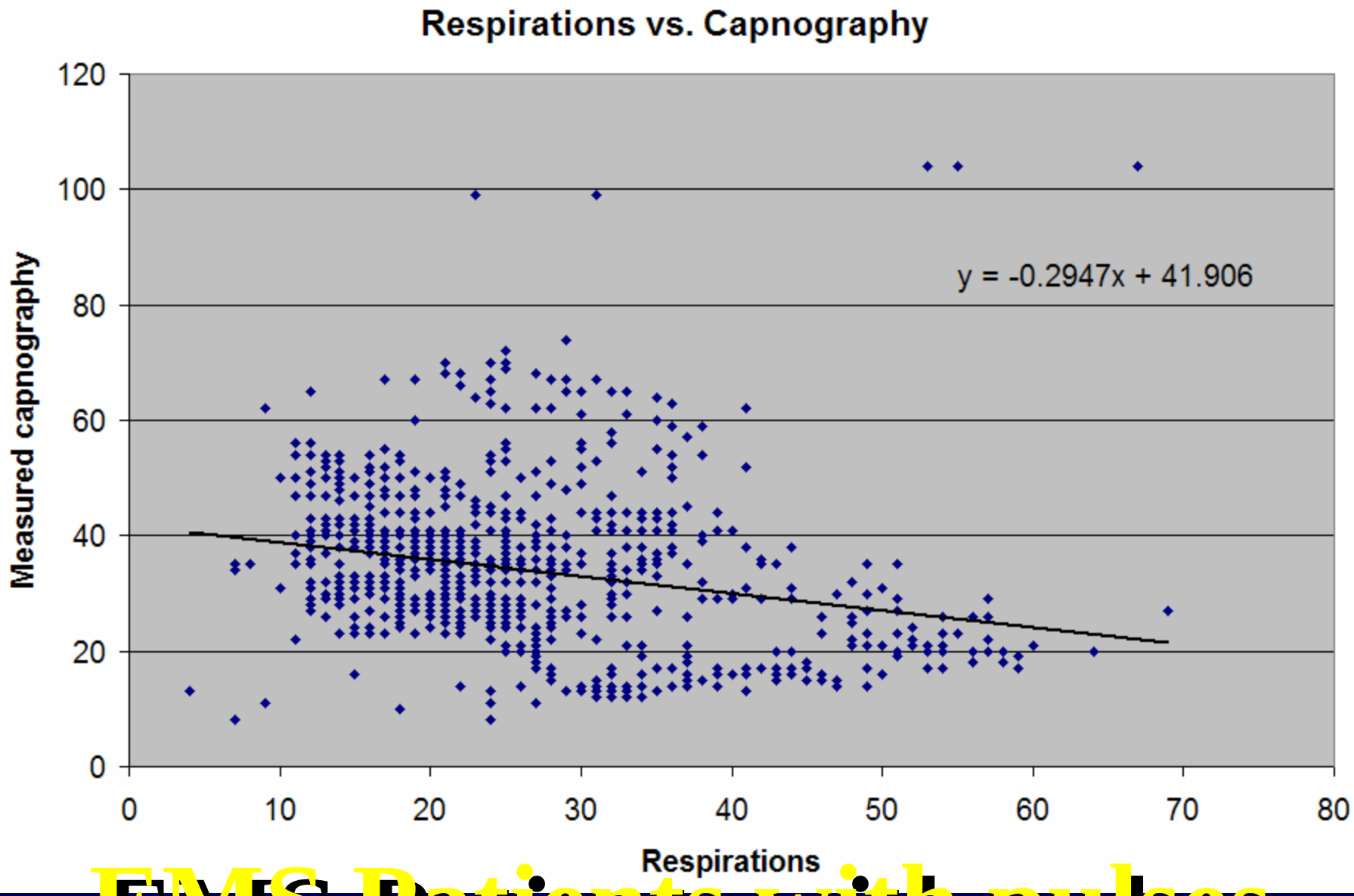

ID#: 070304165531 3Jul04 17:00:43 HR:86 SpO2:--- EtCO2(mmHg) •RR:20•14
Paddles
SpO2(X2) No Sensor Detected
50
CO2
0
x1.0 2.5-30Hz 25mm/sec
A-1 007 3011371-095 2GG4KROKGJSP7R LP1231255100
MEDTRONIC PHYSIO-CONTROL
P/N 805319


ID#: 050304084650 3May04 8:59:35 HR:56 SpO2:81 EtCO2(mmHg) RR:
Apnea Alarm
II
50
CO2
0
x1.0 1-30Hz 25mm/sec
LP1212371118

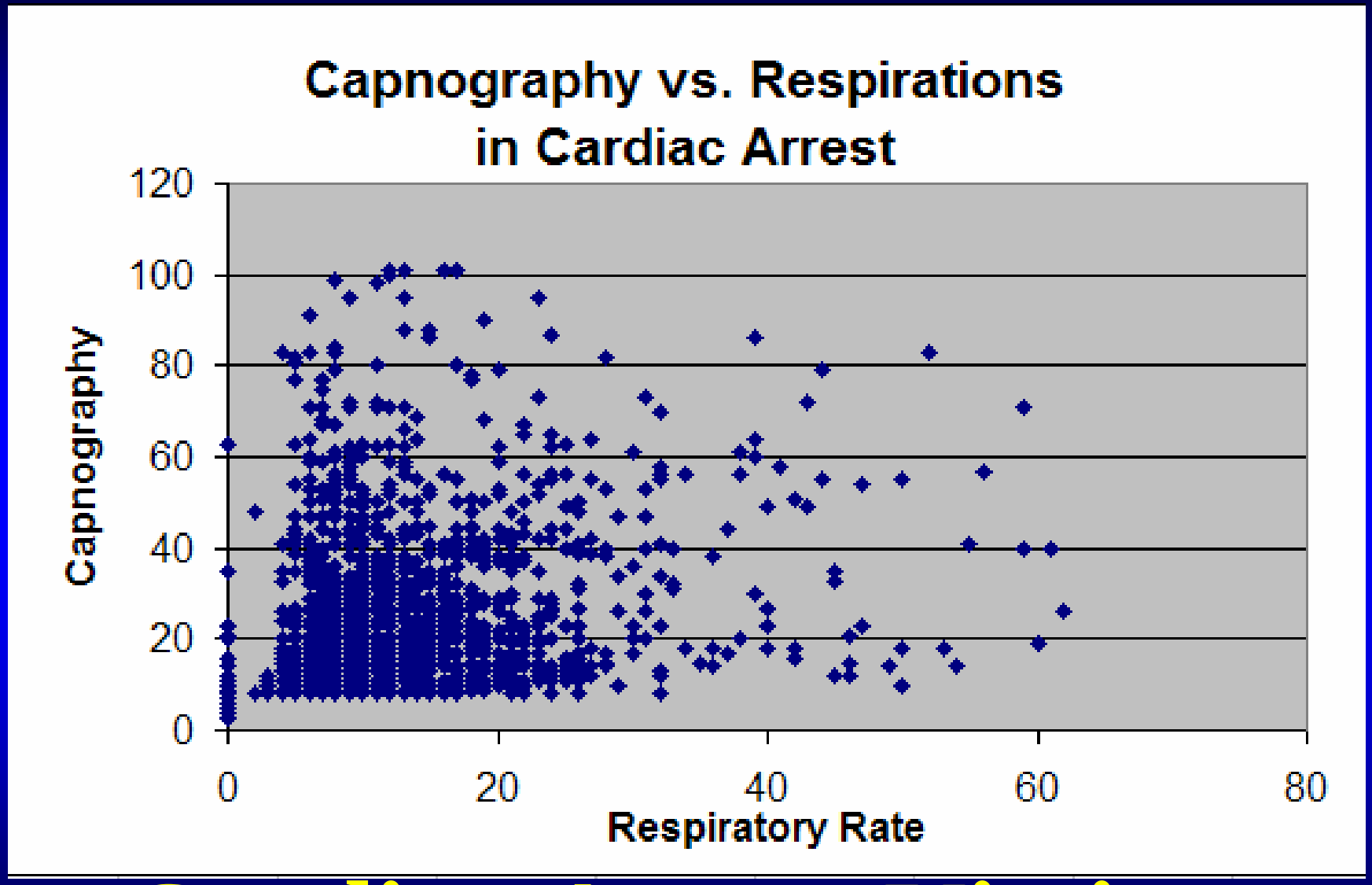
Do YOU make a judgment as to how fast to bag your patients who are critically ill?

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



Cardiac Arrest Victims

…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% CI = 4.594 to 20.558; p < 0.0001);

inability to pass the endotracheal tube through the vocal cords
(7.653; 95% CI = 3.561 to 16.447; p < 0.0001);

inability to visualize the vocal cords
(7.638; 95% CI = 3.966 to 14.707; p < 0.0001);

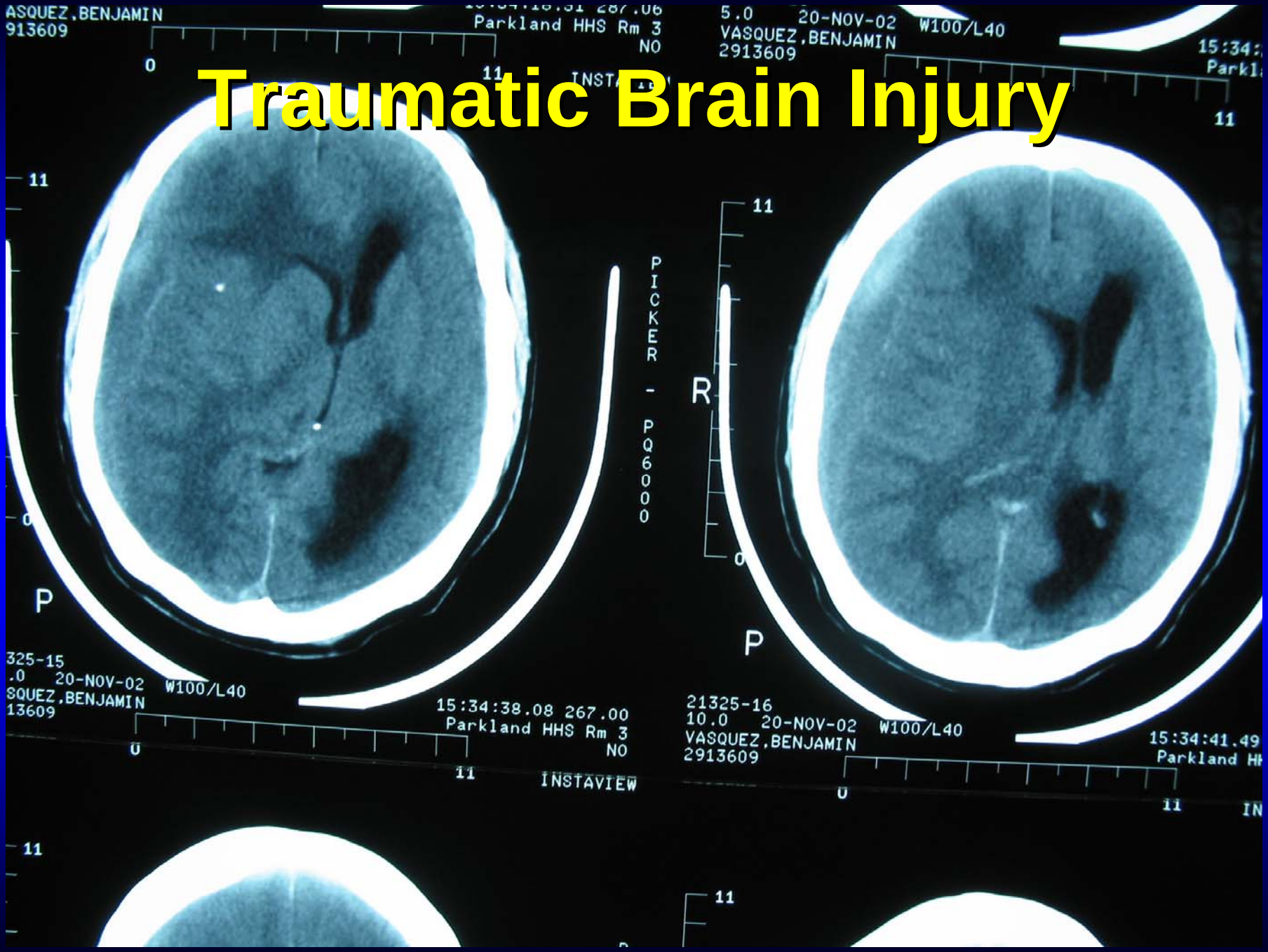
intact gag reflex
(7.060; 95% CI = 3.552 to 14.033; p < 0.0001);

intravenous access established prior to ETI attempt
(3.180; 95% CI = 1.640 to 6.164; p = 0.0005);

increased weight (ordinal scale)
(1.555; 95% CI = 1.242 to 1.947; p = 0.0001);

electrocardiographic monitoring established prior to ETI attempt
(0.199; 95% CI = 0.084 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

LOC-ABC

Worsening mental status

Increased work of breathing

OR

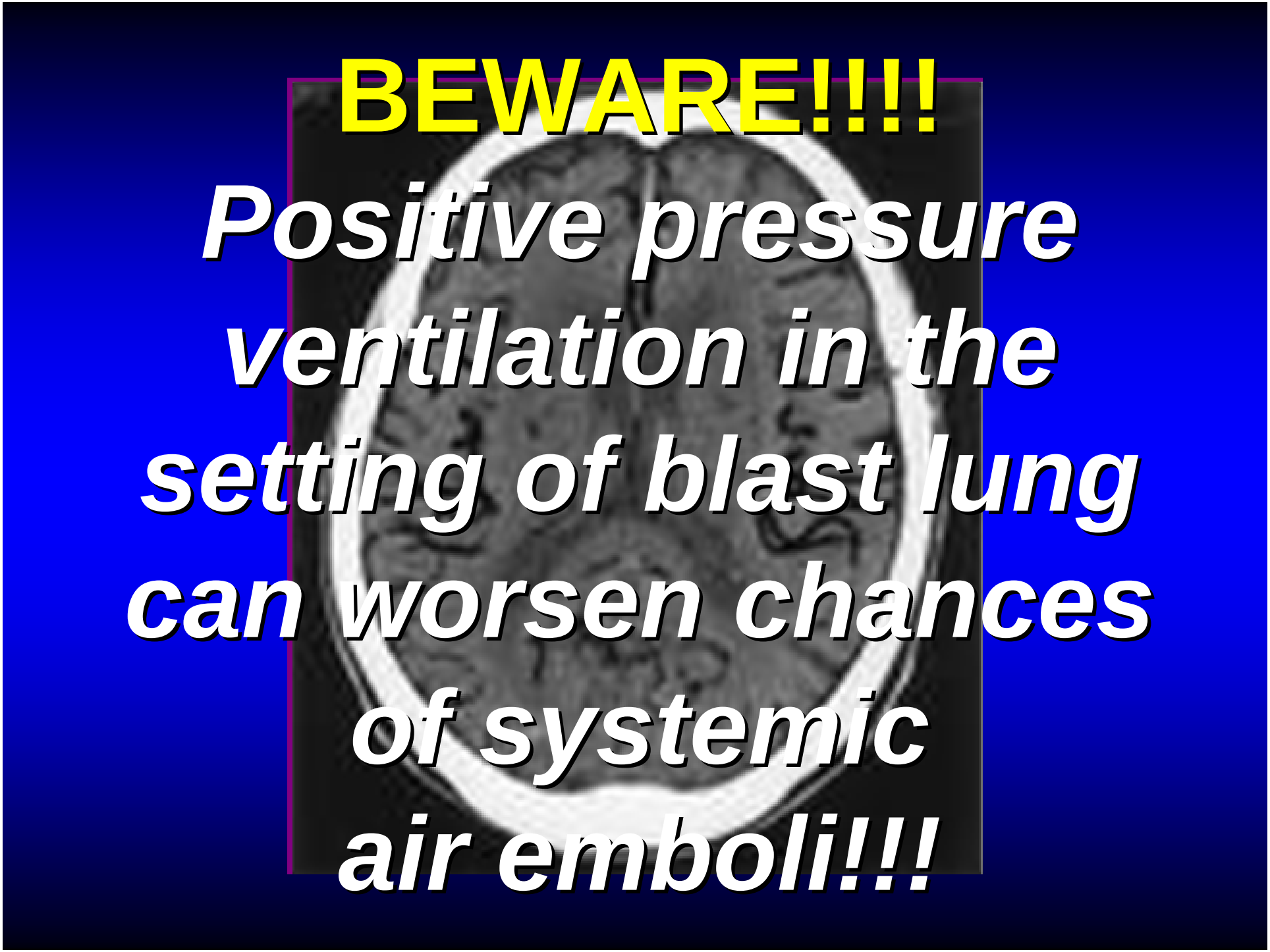
decreased work of breathing with worsening mental status

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:

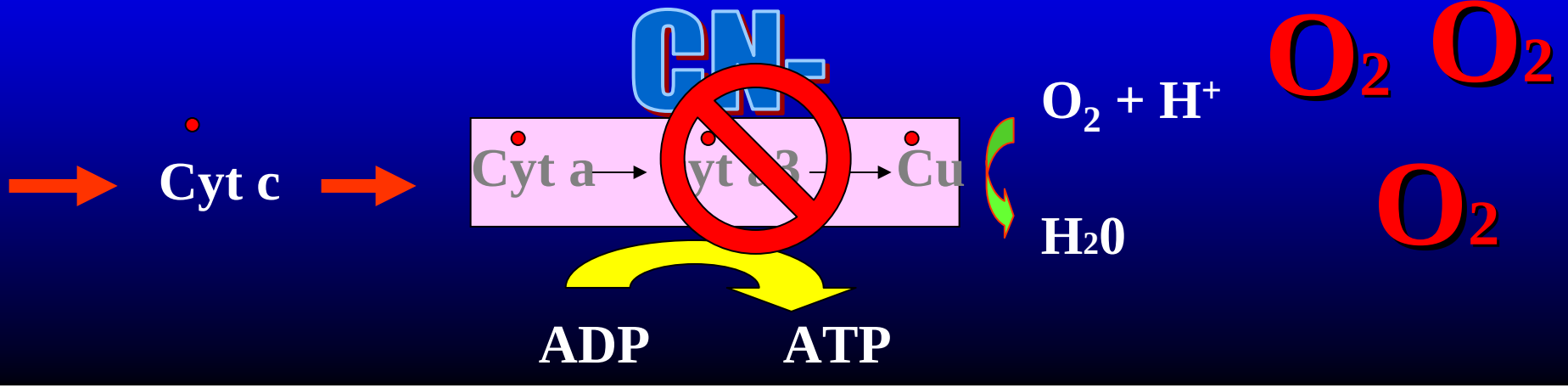
Significantly outside the range of 35 to 45

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).

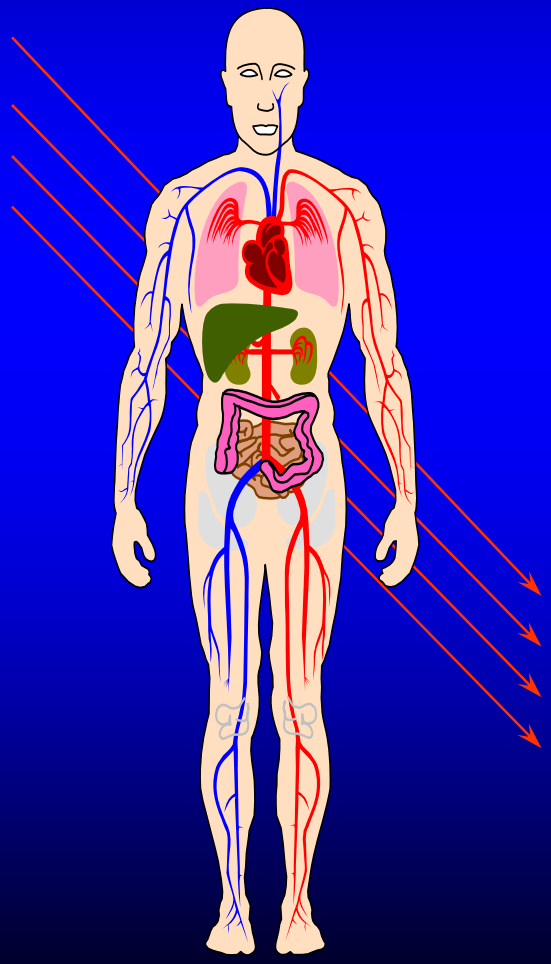
The ratio of Uosm/ Posm appears to be a reliable tool to assess overhydration in Acute Renal Failure

Consider the urinary output as related to water intake, remembering that water output also reflects protein metabolism in the body

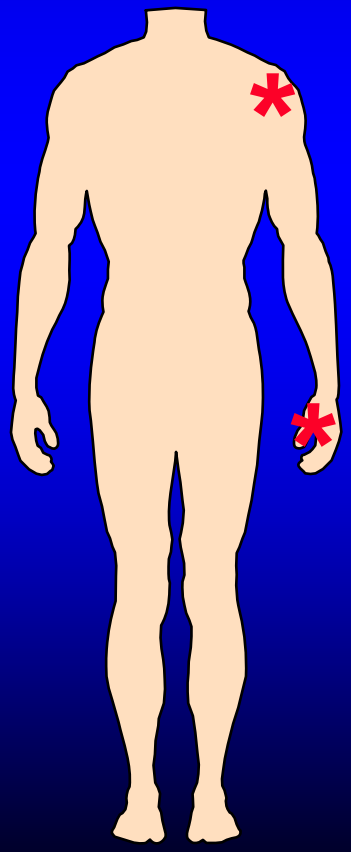
Sepsis usually generates a high cardiac output with a fall in systemic vascular resistance

Clues to “Dirty Bombs”

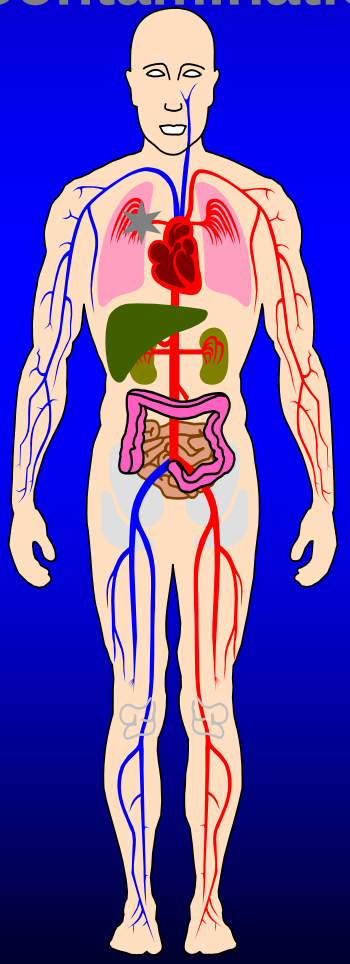
Irradiation



External Contamination

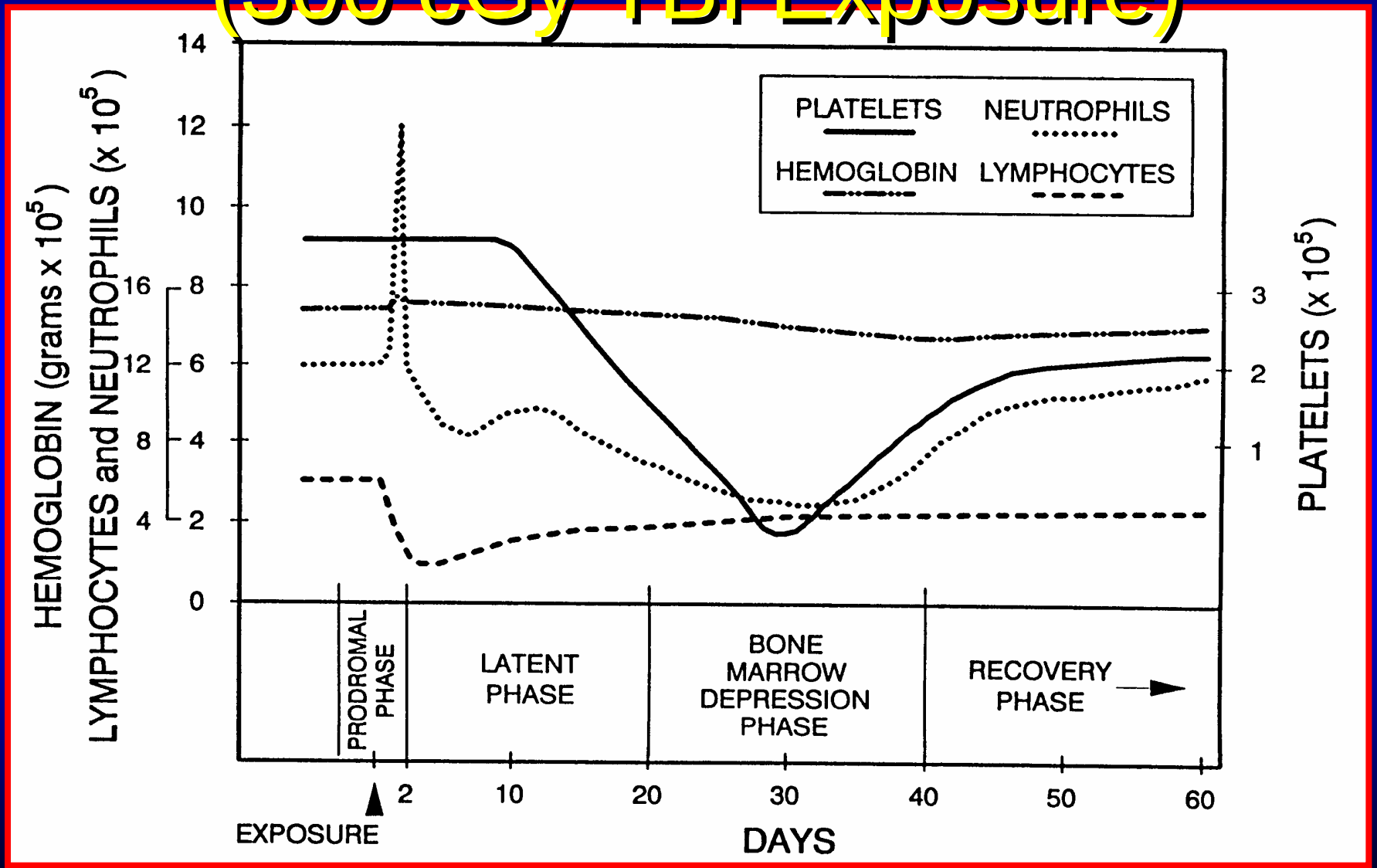


Internal Contamination



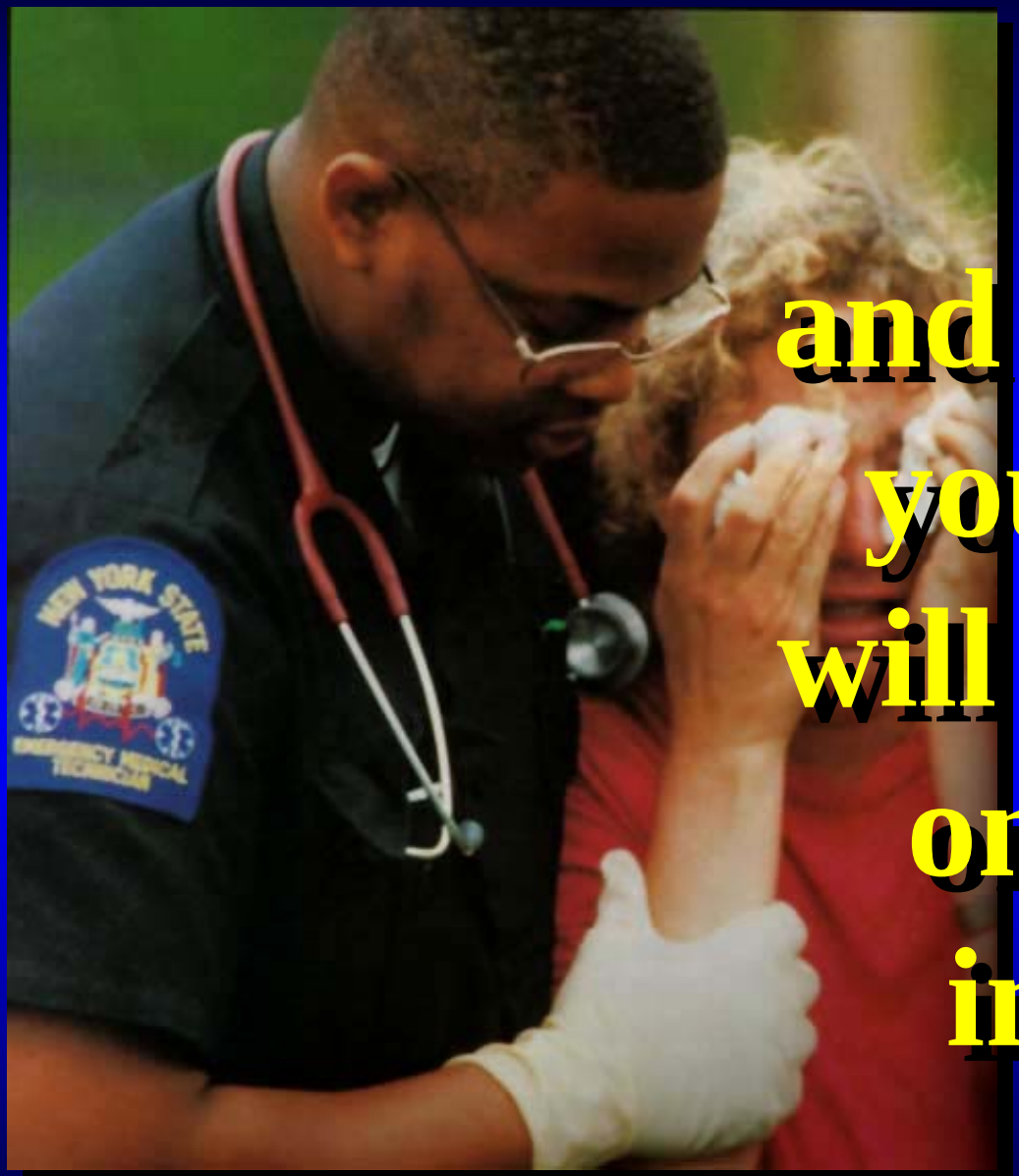
Threshold Exposure (Deterministic Effects) Dose	Threshold	ED_{50}
Oligospermia (2 Yrs)	0.3 Gy	0.7 Gy
Ovulation Suppression (permanent)	0.6 Gy	3.5 Gy
Vomiting	0.5 Gy	2 Gy
Diarrhea	1 Gy	3 Gy
Mortality from Marrow Syndrome (minimal care)	1.5 Gy	3 Gy
Mortality from Marrow Syndrome (supportive care)	2.3 Gy	4.5 Gy
Thyroiditis	2 Gy	12 Gy
Skin - Erythema	3 Gy	6 G
Skin - Dry Desquamation	5 - 20 Gy	20 Gy
Skin - Wet Desquamation	12 - 20 Gy	-
Skin - Necrosis	20 - 30 Gy	-
Mortality from Pulmonary Syndrome Lethality	5 Gy	10 Gy
Mortality from Gastrointestinal Injury	8 Gy	15 Gy
CNS Incapacitation	6.5 Gy	17 Gy
Acute Encephalopathy	5 - 8 Gy	-

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

drray@doctorfowler.com

www.rayfowler.com

www.utsw.ws

"the emergency medicine education website"

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?