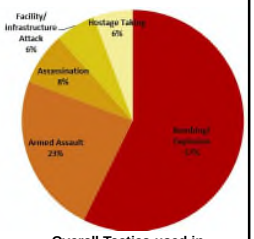

BLAST INJURIES
Ryan Gerecht, MD, CMTE
Medical Director
Tacoma Fire Department
FIRE
TACOMA
DEPT.


BREAKING NEWS
HAMILTON HOME DESTROYED AFTER EXPLOSION
MAN AND WOMAN INSIDE THE HOME AT THE TIME
LIVE
BREAKING NEWS
ON YOUR SIDE
REPORTED HOUSE EXPLOSION IN BETHEL
CREWS CALLED TO SPRING ST.
11 AT 11PM
TEEN GIRL BADLY BURNED IN HOUSE EXPLOSION
GEORGETOWN 16-YEAR-OLD BURNED OVER 80% OF BODY
DEVELOPING NOW
ON YOUR SIDE
BLAST CAUGHT ON CAMERA
GRAIN ELEVATOR EXPLOSION


Thank You

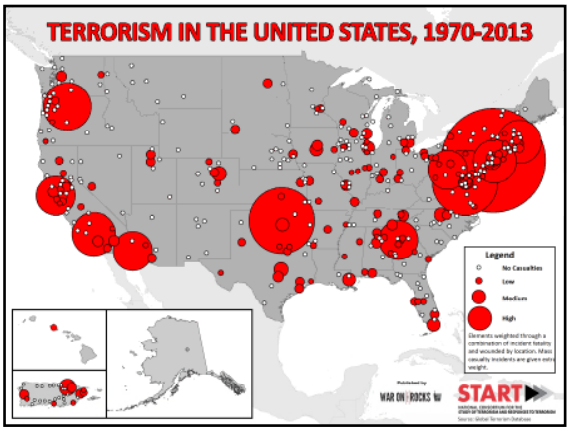
THE REALITY

- Average number of illegal bombings per day in the US: 5
- Total of 36,110 bombing incidents causing almost 700 deaths from 1983 – 2002
- Most accidental explosive injuries occur from handling unexploded ordinance such as grenades and ammunition

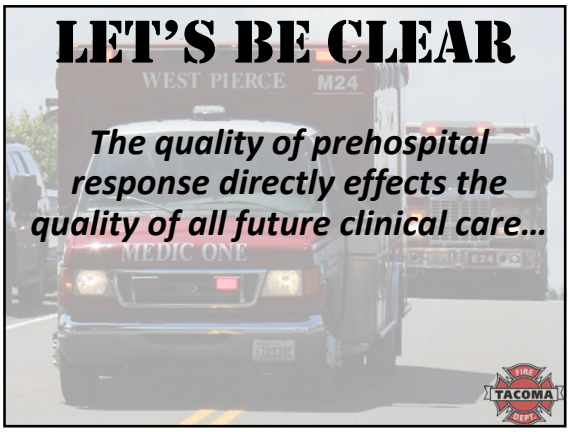


Overall Tactics used in Terrorist Attacks

J Trauma. 2005 Dec;59(6):1436-44.
The United States twenty-year experience with bombing incidents: implications for terrorism preparedness and medical response. Kapur GB1, Hutson HR, Davis MA, Rice PL.



LET'S BE CLEAR

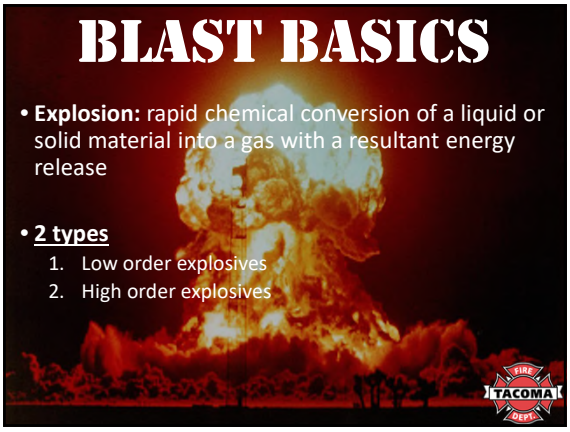


The quality of prehospital response directly effects the quality of all future clinical care…

OBJECTIVES

- **Introduction to blast terminology**
- **Classification of blast injuries**
- **Common injury patterns**
- **Basic management principles**

BLAST BASICS



- **Explosion:** rapid chemical conversion of a liquid or solid material into a gas with a resultant energy release
- **<u>2 types</u>**
  1. Low order explosives
  2. High order explosives

BLAST BASICS

- **Low order explosives:** release energy slowly through deflagration (burning). Slow build up of pressure with burning in confinement
  - Black powder
  - Flash powder
  - Smokeless powder
  - Pipe bombs
- **No over-pressurization wave**
- Produces injury as a result of fragmentation, blast wind (not blast wave) and thermal injury

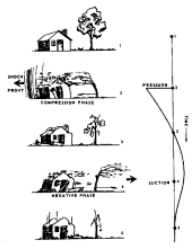
BLAST BASICS

- **High order explosives:** release energy rapidly through detonation. Produces a supersonic over-pressurization shock wave
  - TNT
  - C-4
  - Semtex
  - Nitrogylcerin
  - Ammonium nitrate fuel oil
- **PRODUCES BLAST WAVE**

BLAST BASICS

- **Detonation:** almost instantaneous transformation of the physical space occupied by original solid / liquid material into gases.
  - Gas fills the same volume within a few microseconds, expanding under extremely high pressure
  - The highly pressurized gases compress the surrounding environment, generating a pressure pulse that is propagated as a blast wave

BLAST WAVE
vs.
BLAST WIND



- **Blast Wave:** the intense over pressurization impulse created by HE explosives
- **Blast wind:** forced super-heated air flow that can occur with HE or LE explosives

Figure 3-III. Variations of Blast Effects Associated with Positive and Negative Phase Pressures with Time

Explosive Train

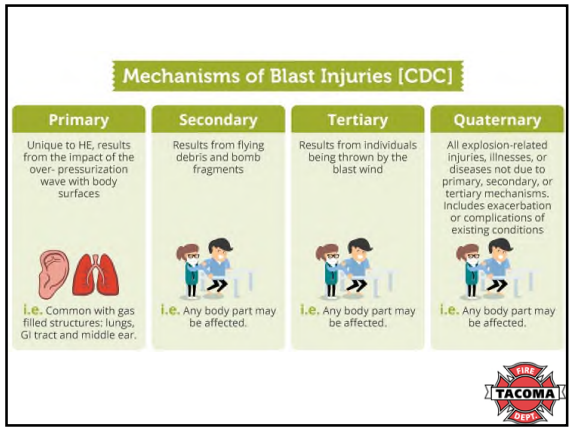
- Sequence of energetic materials begin with priming or initiating material (primer or fuze), through boosting material, and finally to the main charge
- Sequence is typically from low-yielding, but very sensitive material (primary explosive) to a high-yielding, but not as sensitive material (high explosive)

FUZE → **BOOSTER** → **MAIN CHARGE**

High — Sensitivity → Low

Small — Quantity → Large

PRIMER → **PROPELLANT**



PRIMARY

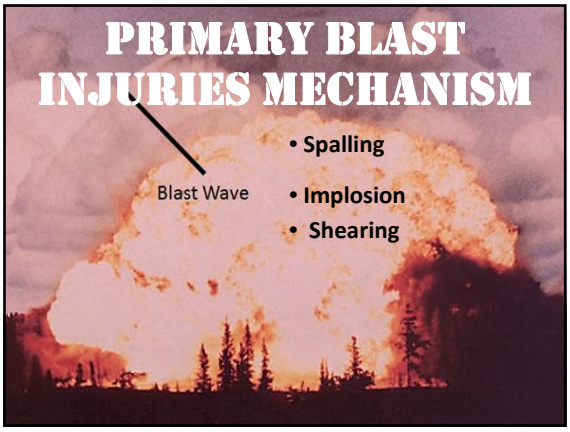
- Direct effects of blast wave pressure (barotrauma)
- Most commonly injures air-filled organs & air-fluid interfaces
- Unique to high order explosives

PRIMARY

Most important Injuries

1. Rupture of tympanic membranes
2. Pulmonary damage and air embolization
3. Rupture of hollow viscera
4. Head injuries

PRIMARY BLAST INJURIES MECHANISM



PRIMARY BLAST INJURIES MECHANISM

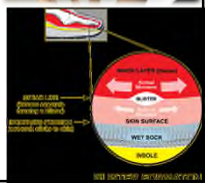
Implosion

- ✓ Entrapped gases in hollow organs compressing then expanding → visceral disruption

Shearing

- ✓ Caused by tissues of different densities moving at different speeds → visceral tearing

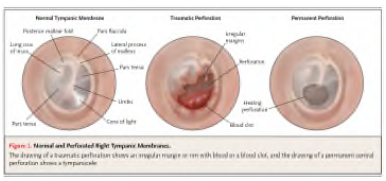
Major cause of injury



TYMPANIC MEMBRANE

- The structure most frequently injured & at the lowest pressure (5 psi above atmospheric pressure)

- **Symptoms**
  - ✓ Pain
  - ✓ Deafness
  - ✓ Tinnitus
  - ✓ Vertigo
  - ✓ Hemorrhage

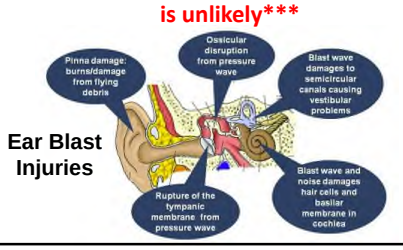


❖ **Impaired hearing may complicate triage…**

TYMPANIC MEMBRANE

Classic Teaching (Not entirely true)

*****No rupture of the tympanic membrane… then primary injury of other air-containing organs is unlikely*****



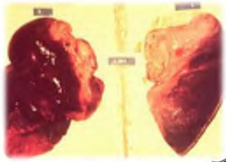
Ear Blast Injuries

TYMPANIC MEMBRANE

- Spontaneous healing occurs in 50-80% of patients with perforations
- **Treatment**
  - ✓ Follow standard trauma protocols for lifesaving measures
  - ✓ Cover the ear to reduce pain from wind/cold air
  - ✓ Manage ear soft tissue injuries
  - ✓ Transport for evaluation
  - ✓ Maintain a high suspicion for other injuries
  - ✓ Transient hearing loss resolves in hours

BLAST LUNG

- 2nd most susceptible organ to primary blast injury
- Caused by blast wave against the chest wall
- Pressure differences across alveolar-capillary interface cause:
  - ✓ Hemorrhage
  - ✓ Pulmonary contusion
  - ✓ Pneumothorax
  - ✓ Hemothorax
  - ✓ Pneumomediastinum



❖ **Most common fatal injury among initial survivors**

BLAST LUNG

- Signs of blast lung are usually present on initial eval but have been reported as late as 48 hours after explosion
- Immediate onset of pulmonary edema = grave prognosis
- ❖ May occur without obvious external injury to the chest
- ❖ Body armor does **NOT** protect against barotrauma of blast

BLAST LUNG

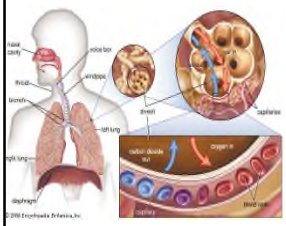
- **Classic Triad**
  1) Apnea
  2) Bradycardia
  3) Hypotension
- **Clinical Presentation**
  - Tachypnea
  - Apnea
  - Shortness of breath
  - Hypoxia
  - Cyanosis
  - Dec. breath sounds
  - Hemodynamic instability
  - Wheezing
  - Subcutaneous crepitus
  - Hemoptysis
  - Cough
  - Chest pain

BLAST LUNG

Management

- **ABC's**
- **High flow oxygen** to prevent hypoxemia
- ❖ **Be careful with use of positive pressure ventilation**
  - ✓ May increase risk of alveolar rupture, ptx, air embolism
- **Needle decompression** as needed
- ❖ **Conservative fluid administration**
  - ✓ Too much fluid may worsen pulmonary status
- **Position** head down left-lateral recumbent

AIR EMBOLISM



- Responsible for most early sudden deaths
- Result from alveolar-capillary fistulae
- Air in the blood stream can result in obstruction of any vascular bed

AIR EMBOLISM

- **Symptoms** are dependent on the location of the arterial blockage
  - ✓ **CNS:** focal neuro deficit
  - ✓ **Coronary arteries:** arrest / STEMI
  - ✓ **Retinal arteries:** vision loss
  - ✓ **Abdominal arteries:** bowel ischemia

AIR EMBOLISM

- **<u>Management</u>**
  - ✓ ABC's
  - ✓ Supplemental oxygen
  - ✓ Position body appropriately
    - Head down left-lateral decubitus
  - ✓ Positive pressure ventilation
    - concerns regarding further barotrauma
  - ✓ Hyperbaric therapy

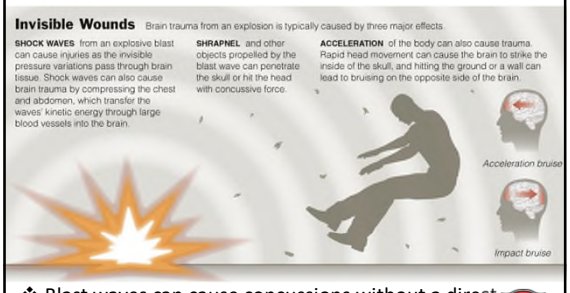
BLAST ABDOMEN

- Most common injury is abdominal organ hemorrhage and perforation
- Colon is most frequently affected (more air)
- Rupture, infarction, ischemia, & hemorrhage of solid organs assoc with high blast force or close proximity to blast center
  - ✓ Liver & Spleen
  - ✓ Kidney

OTHER PRIMARY INJURIES

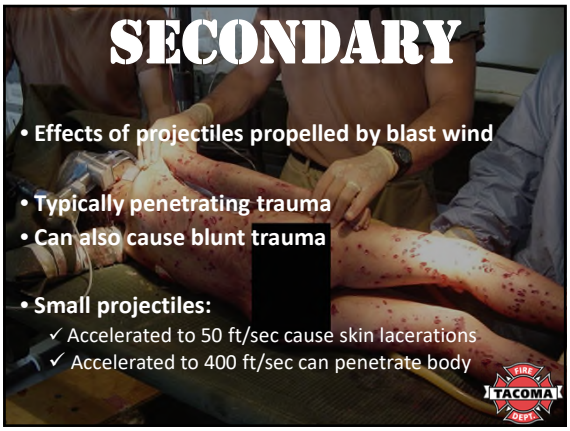
- Eye: ruptured globe, retinitis, hyphema
- Facial fractures
- Traumatic brain injury: concussion

BLAST BRAIN



❖ Blast waves can cause concussions without a direct blow to the head


DO NOT FORGET
Primary Blast Injury may NOT cause visible trauma

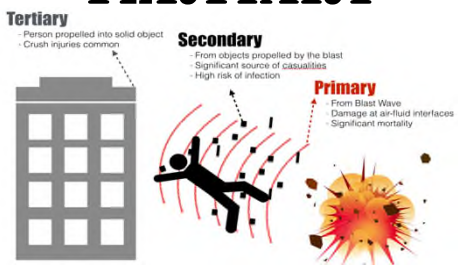

SECONDARY
• Effects of projectiles propelled by blast wind
• Typically penetrating trauma
• Can also cause blunt trauma
• Small projectiles:
✓ Accelerated to 50 ft/sec cause skin lacerations
✓ Accelerated to 400 ft/sec can penetrate body


Leading cause of death & injury in military & civilian terrorist attacks,
except in the case of major building collapse

MANAGEMENT

- MARCH
- Early tourniquet use & Combat Gauze
- Permissive hypotension
- Minimize Lethal triad
- Junctional Injuries
- Splint

TERTIARY



- **Thrown by the blast wind and structural collapse**
- Bodies flying through the air = blunt trauma
- Collapse = higher rate of death due to entrapment

CRUSH SPECTRUM

- **Crush injury:** the anatomic injury associated with direct trauma due to a compressive force

- Extended entrapment with compression **MAY** cause
  - Traumatic rhabdomyolysis
  - Crush syndrome
  - Compartment syndrome

❖ **These are similar but different entities that may be present alone or together…**

CRUSH SPECTRUM

- **Traumatic Rhabdomyolysis:** just one cause of rhabdo
  - Prolonged immobilization
  - Excited delirium
  - Extreme sports or exertion

  } Other causes
- **Crush syndrome:** is the systemic manifestation of skeletal muscle injury from extended compression
- **Compartment syndrome** increase in pressure within a fascial compartment that compromises blood flow & can progress to rhabdomyolysis

CRUSH SYNDROME

- **Localized crush injury + systemic manifestations**
  - ✓ **Acidosis**
  - ✓ **Hyperkalemia & Hypocalcemia**
  - ✓ **Organ dysfunction**
- **Systemic manifestations are due to ischemia reperfusion injury of skeletal muscle**
- **Crush syndrome causing ARF is the 2nd only to direct trauma in causing death following disasters**

CRUSH SYNDROME

- **Critical Risk Factors for Crush Syndrome**
  1. **Mass of muscle injured**
  2. **Ischemia time**
- **Critical muscle mass necessary to put an entrapped patient at risk for crush syndrome is poorly defined… but it is more than a hand or foot**
- **At normal body temp critical ischemia time is around 4 hours**

CRUSH SYNDROME

- Clinical Presentation
  1. Hypotension:
     - Third spacing fluid (> 12L in 1st 48 hours)
  2. Renal Failure
     - Myoglobin & uric acid
     - Hypotension
  3. Metabolic abnormalities
     - Hypocalcemia, Hyperkalemia, Lactic acidosis
  4. Hypothermia/hyperthermia

CRUSH SYNDROME MANAGEMENT

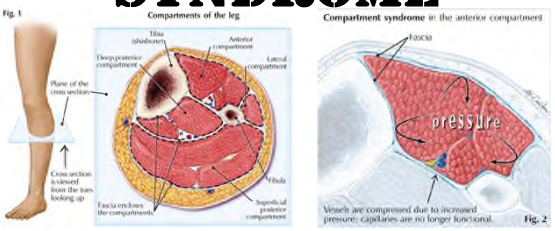
- Limb stabilization and hemorrhage control
- Monitor for cardiac arrhythmias
- IV fluids (1 liter bolus + 1.5L/hour)
- Bicarb (1mEq/kg bolus every hour or so)
- Calcium gluconate or calcium chloride

THE BIG LIFT

- Reperfusion Syndrome
  - Cardiovascular instability due to massive fluid shift, electrolyte abnormalities & direct myocardial toxicity
  - Patient may look stable until extricated…

❖Coordinate with the rescue officer
❖Think ahead
❖Resuscitate BEFORE the lift
❖Pretreat for hypovolemia & hyperkalemia

COMPARTMENT SYNDROME

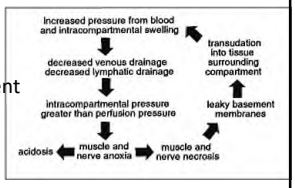


- Can be a secondary complication of crush injury
- Third spacing fluid

COMPARTMENT SYNDROME

Symptoms

- ✓ Pain out of proportion
- ✓ Pain with passive movement
- ✓ Pallor
- ✓ Paresthesia
- ✓ Paralysis
- ✓ Poikilothermia
- ✓ Pulseness



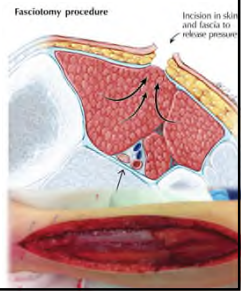
Typical Sites

- Upper & lower ext
- Feet & hands

COMPARTMENT SYNDROME

Management

- Standard trauma treatment
- Immobilize affected part
- Pain control & Anxiolytics
- Begin resuscitation
- Treat for crush syndrome if also present



QUATERNARY

- All other explosion-related injuries & illnesses
- Exacerbation of preexisting medical problems
- Burns & Toxic inhalation (CO & cyanide)
- Exposure to radiation
- Inhalation of dust containing coal or asbestos

BLAST BURNS

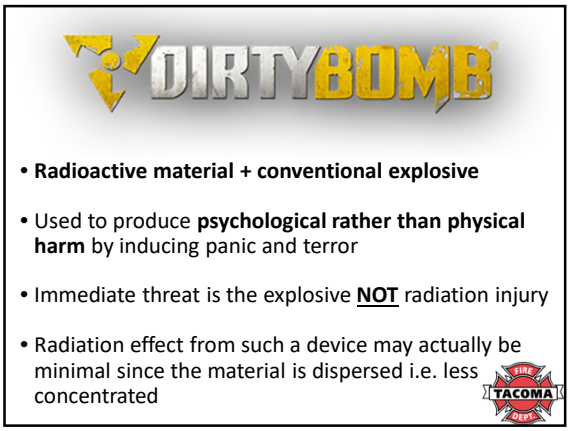
- Rapidly expanding fireball may cause flash burns
- Confined space explosions increase the risk of inhalation injury (18% of initial survivors)
- Most bomb related burns cover < 20% of the TBSA but occur in combination with other blast injuries
- Challenge: conflicting fluid requirements with blast lung

COMBINED BLAST INJURIES

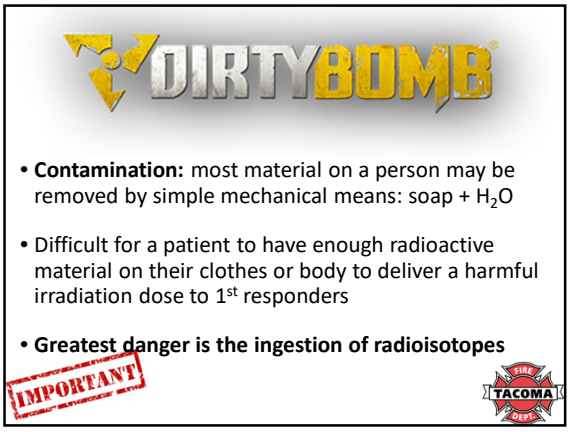
- Combined injuries especially blast + burn or blast + crush injury, are common.
- Don't develop tunnel vision on what appears to be the worst injury

QUINARY

- **Intentional addition of radiological, chemical, or biological compounds to the explosive device**



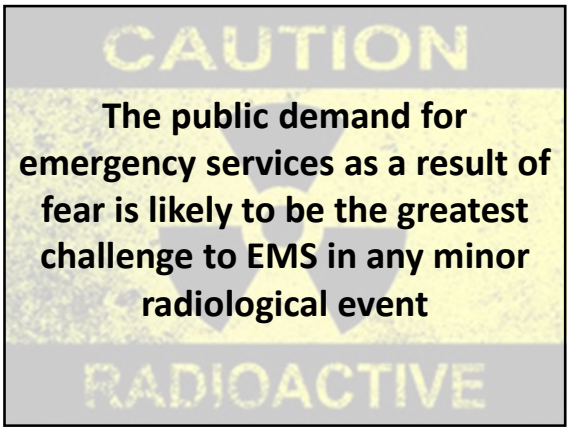
- **Radioactive material + conventional explosive**
- Used to produce **psychological rather than physical harm** by inducing panic and terror
- Immediate threat is the explosive **NOT** radiation injury
- Radiation effect from such a device may actually be minimal since the material is dispersed i.e. less concentrated



- **Contamination:** most material on a person may be removed by simple mechanical means: soap + H_2O
- Difficult for a patient to have enough radioactive material on their clothes or body to deliver a harmful irradiation dose to 1st responders
- **Greatest danger is the ingestion of radioisotopes**

IMPORTANT

- Immediately don **N-95 or greater respiratory mask**
- **Universal precautions** protects against radiological secondary contamination of 1st responders
- Triage & **life saving procedures should NOT be delayed** because of the possibility of radioactive contamination of the victim… the risk of exposure to you is very very small

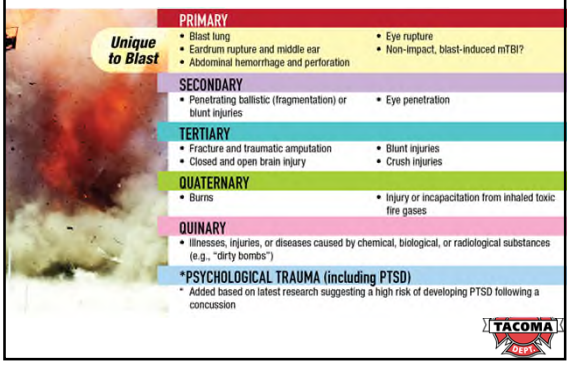


ADDITIONAL INFORMATION

- Incident command
- Special populations: children, elderly, pregnant
- Chemical Bombs
- Hidden secondary devices
- "Dirty bombs" and "Smart bombs"

https://www.acep.org/blastinjury/

CONCLUSION



CONCLUSION

- Primary blast injury may not cause visible trauma
- Use tourniquets often and early
- Crush syndrome
- Combination injuries…
- Don't be a part of the "dirty bomb" panic
- We set the tone & start the momentum for how these events will be handled…