2024 Trauma Panel:

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Panel Objectives

1. Discuss the importance of having a mass casualty plan at every hospital
2. Describe and apply triage tools to be used during mass casualty events
3. Apply alternative anesthetic techniques (i.e., TIVA) during mass casualty events or disasters
4. Discuss management of common trauma injuries encountered in during mass casualty events, including blast and crush injuries

Mass Casualty Incident Protocols

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Disclosures

No financial disclosures

Learning Objectives

- Recognize the types possible mass casualty incidents (MCIs)
- List the three types of events most likely to occur at your institution
- Sketch a strategy for anesthesiology mass casualty response at your institution

Mass Casualty Incident (MCI) Types


Natural **v.** **Human-Made**

Mass Casualty Incident (MCI) Types

Natural Disasters
- Earthquakes
- Weather (Floods, Hurricanes, Tornados)
- Infectious Disease Pandemics

Human-Made Disasters
- Mass shootings
- Bombings
- Vehicular accidents (car, rail, airplane)
- Fires
- Radiation exposure
- Biochemical weapons
- Nuclear weapons

MCI Statistics

Developing MCI Protocols

Developing MCI Protocols

Partners in MCE
- First Responders
- Emergency Department
- Department of Surgery
- Nursing and Surgical Techs
  - Pre-Op/PACU
  - OR Nursing
  - ICU Nursing
- Department of Radiology
- Blood Bank/Lab
- Sterile Processing

Developing MCI Protocols

Anesthesiology MCI Protocol
- Triage/Control Manager (no clinical responsibilities if possible)
- System for Calling In Backup
- Continuous communication between Trauma Surgery, Anesthesiology, and OR Charge Nurse

ASA Mass Casualty Checklist

References

1. Kuza C, McIssac JH. Emergency Preparedness and Mass Casualty Considerations for Anesthesiologists. Advances in Anesthesia (2018) 36: 39-66.
2. O'Neill SB, Gibney B, O'Keeffe ME, Barrett S, Louis L. Mass Casualty Imagine - Polity, Planning, and Radiology Response to Mass Casualty Incidents. Canadian Association of Radiologist's Journal (2020) 71(3): 388-395.
3. Perate AR. Pediatric Mass Casualty Preparedness. Anesthesiology Clin (2020)38:509-516
4. Bazyar J, Farrokhi M, Khankeh H. Triage Systems in Mass Casualty Incidents and Disasters: A Review Study with A Worldwide Approach. J Med Sci (2019) 7(3): 482-494.

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Triage Tools and Alternative Techniques

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Objectives

- Describe and apply triage tools for use at mass casualty events
- List and perform alternative anesthetic techniques (i.e., field TIVA) for use in resource-limited disaster settings

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Triage Tools

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Stages

- Primary
  - Scene
- Secondary
  - EMS
- Tertiary
  - ED, trauma center, hospital triage area

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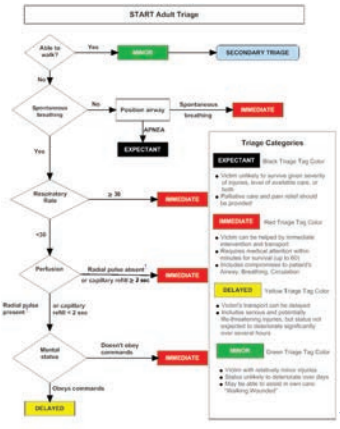

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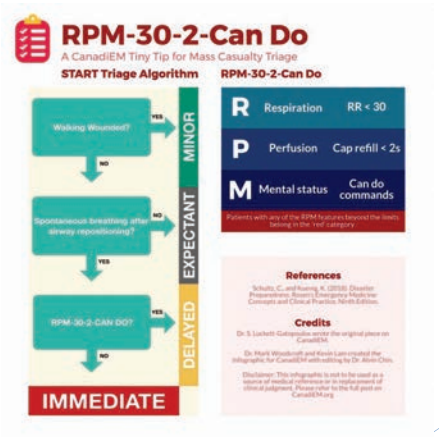
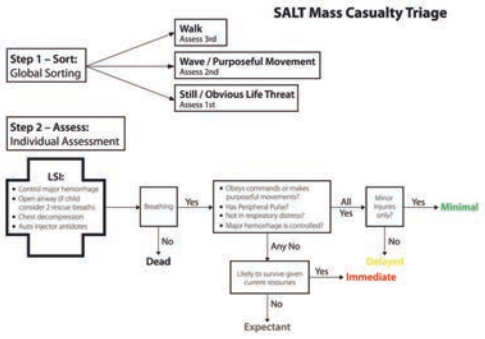




Lerner EB. Disaster Med Public Health Prep 2011.

START vs. SALT

- SALT
  - Quick application
  - Improved clinician confidence
  - Acceptable undertriage

Lerner EB. Prehosp Emerg Care 2010.
Cone DC. Prehosp Emerg Care 2009.

Anesthetic Techniques

Field TIVA
Low Flow Anesthesia
Regional

TIVA

TIVA vs. Volatiles?

"At present, available experimental data do not support the selection of one anesthetic agent over the others"

Schifilliti D. CNS Drugs 2010.

TIVA and TBI

- 252 combat casualties with TBI requiring neurosurgery
- TIVA vs. volatiles
  - TIVA: propofol + opioid +/- ketamine
  - Volatiles: sevo or iso
- No difference in outcomes / neurological recovery

Grathwohl KW. Anesthesiology 2008.

FIELD TIVA

- Supplies
  - 100 mL saline bag
  - 2 x 20 mL propofol
  - Ketamine (50 mg/mL)
  - Fentanyl (50 mcg/mL)
  - Macro dripper
    - (20 gtt = 1 mL)

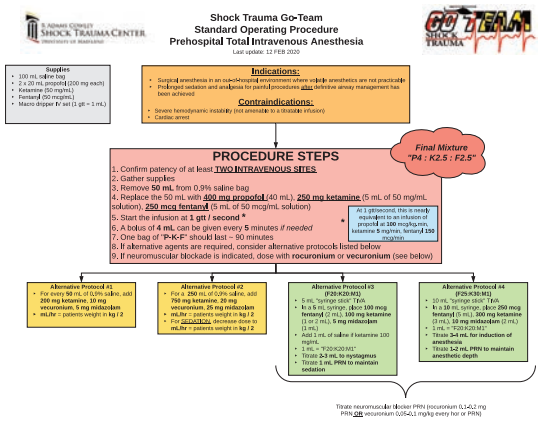
FIELD TIVA

- Remove 50 mL from saline bag
- Replace with:
  - Propofol 400 mg (40 mL)
  - Ketamine 250 mg (5 mL of 50 mg/mL soln.)
  - Fentanyl 250 mcg (5 mL of 50 mcg/mL soln.)

Final mixture "P4-K2.5-F2.5"

Field TIVA Titration

- 4 mL bolus every 5 minutes
  - Similar to propofol 100 mcg/kg/min, ketamine 5 mg/min, fentanyl 150 mcg/30 min
- 1 gtt/sec
  - Titrate down once incision made
  - Stop 10 minutes before completion of surgery
- 1 bag of PKF should last ~ 90 minutes



Galvagno SM. BMJ Emerg Med 2021.

TIVA (BOUZAT Protocol)

- Ketamine 2-3 mg/kg/hr
- Sufentanil 0.2-0.3 mcg/kg/hr
- Cisatracurium 0.2 mg/kg/hr
  - Atracurium 0.5 mg/kg/hr

CHU GRENOBLE ALPES

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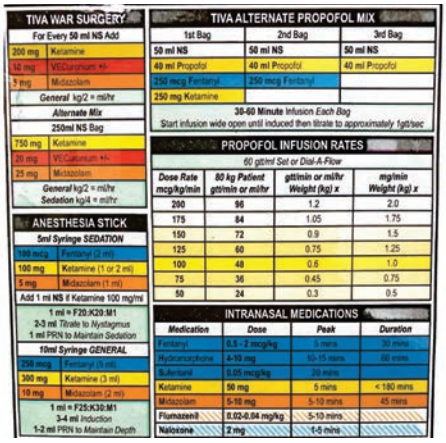

TIVA WAR SURGERY	
For Every 50 ml NS Add	
200 mg	Ketamine
10 mg	VECuronium +/-
5 mg	Midazolam
General kg/2 = ml/hr	
Alternate Mix	
250ml NS Bag	
750 mg	Ketamine
20 mg	VECuronium +/-
25 mg	Midazolam
General kg/2 = ml/hr Sedation kg/4 = ml/hr	

ANESTHESIA STICK	
5ml Syringe SEDATION	
100 mcg	Fentanyl (2 ml)
100 mg	Ketamine (1 or 2 ml)
5 mg	Midazolam (1 ml)
Add 1 ml NS if Ketamine 100 mg/ml	
1 ml = F20:K20:M1 2-3 ml Titrate to Nystagmus 1 ml PRN to Maintain Sedation	
10ml Syringe GENERAL	
250 mcg	Fentanyl (5 ml)
300 mg	Ketamine (3 ml)
10 mg	Midazolam (2 ml)
1 ml = F25:K30:M1 3-4 ml Induction 1-2 ml PRN to Maintain Depth	

TIVA ALTERNATE PROPOFOL MIX		
1st Bag	2nd Bag	3rd Bag
50 ml NS	50 ml NS	50 ml NS
40 ml Propofol	40 ml Propofol	40 ml Propofol
250 mcg Fentanyl	250 mcg Fentanyl	
250 mg Ketamine		
30-60 Minute Infusion Each Bag Start infusion wide open until induced then titrate to approximately 1gtt/sec		

PROPOFOL INFUSION RATES

60 gtt/ml Set or Dial-A-Flow

Dose Rate mcg/kg/min	80 kg Patient gtt/min or ml/hr	gtt/min or ml/hr Weight (kg) x	mg/min Weight (kg) x
200	96	1.2	2.0
175	84	1.05	1.75
150	72	0.9	1.5
125	60	0.75	1.25
100	48	0.6	1.0
75	36	0.45	0.75
50	24	0.3	0.5

INTRANASAL MEDICATIONS

Medication	Dose	Peak	Duration
Fentanyl	0.5 - 2 mcg/kg	5 mins	30 mins
Hydromorphone	4-10 mg	10-15 mins	60 mins
Sufentanil	0.05 mcg/kg	20 mins	
Ketamine	50 mg	5 mins	< 180 mins
Midazolam	5-10 mg	5-10 mins	45 mins
Flumazenil	0.02-0.04 mg/kg	5-10 mins	
Naloxone	2 mg	1-5 mins	

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Low Flow Anesthesia

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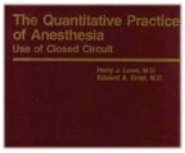
Low Flow Anesthesia

- Conservation of liquid anesthetic
- Less vapor discharge into the air
- Higher inspired gas humidity (less heat loss / drying of airways)
- Earlier detection of leaks in the circuit
- Cheap VO_2 monitor



Lowe HJ & Ernst EA. 1981.

Disadvantages

- Requires gas analyzer
- Water-induced failure of machine
- Rapid titrations difficult (?)
- Sevoflurane?
  - Ok to use down to 0.5 L/min

Bedford RF. Anesth Analg 2000.

ASA. Statement on Use of Low Gas Flows with Sevoflurane (18 Oct 2023, www.asahq.org)

Kennedy RR. Anaesth Intensive Care 2019.

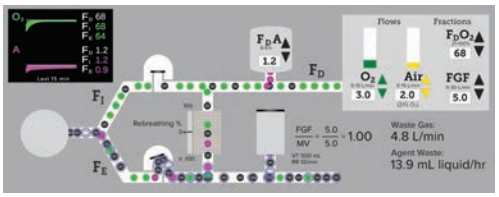
Oxygen Consumption

- VO_2 = 10 x wt (kg) $^{0.75}$
- Children weighing less than 10 kg:
  - O_2 (ml/min) = 6.8 × weight (kg) + 8.
  - More than 10 kg:
    - O_2 (ml/min) = 4.0 × weight (kg) + 35.8
- Rough guide:
  - Adults: 3-4 mL/kg/min
  - Children: 4-8 mL/kg/min
- Oxygen flowmeter setting
- $V_{FO_2} = VO_2 + (V_F - VO_2) \times F_{IO_2}$
  - V_F = total fresh gas flow
  - V_{FO_2} = oxygen flowmeter setting

No math required!

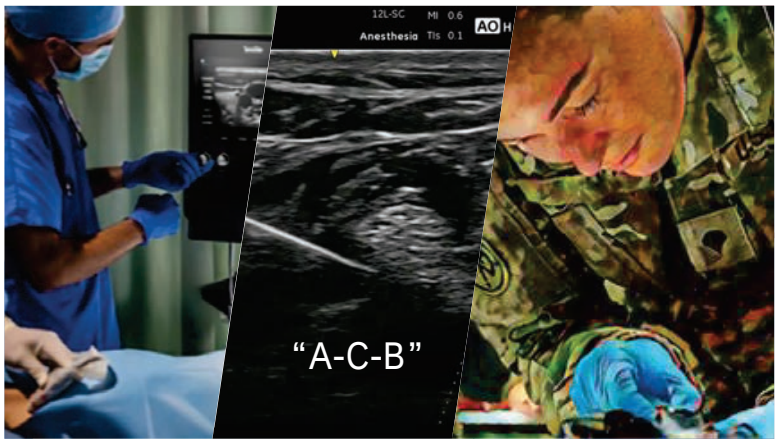
- Start the case normally
- When convenient, close circuit with oxygen set around 200 mL/min
- Watch FIO_2 and bellows / bag
  - Full bellows/bag = wasted anesthetic
  - Adjust mixture of gases according to desired FIO_2
    - Oxygen monitoring is triple redundant
      - Inspired oxygen analyzer
      - End tidal oxygen analyzer
      - Pulse oximeter

ASPF Course



Free!
https://education.asahq.org

Regional



- Triage tools: SALT / START
  - Use one of them!
  - Practice
- Anesthetic techniques
  - TIVA
  - Low flow anesthesia
  - Regional

Common Trauma Injuries of MCI

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Planning for surgical needs for an MCI

- Anesthesia Trauma and Acute Care is similar to disaster response
- We deal with multiple "small diasters" on a daily basis
- We are triage experts
- We are experts in Crisis Resource Management

We all need to practice & train for MCI

- Training and collaboration are essential
- Disaster training drills
- Have an MCI plan, Easier to dial back (size/impact of incident is unclear)
- Planning is essential…but be adaptive!
- Triage, but don't hesitate to go to the OR

What to expect during an MCI…

- Approximately 10% will need to go to OR within 30minutes
- Pediatric Patients account for 10-20% of all casualties
- Many emergent (red tag) patients will arrive in private vehicles
- Essential to *Triage and Re-Triage* non-urgent (green) patients—assign staff to each

- Active shooters:
  - 98% act alone
  - 93% plan it out
  - 90% commit suicide
- Expect more patients needing OR immediately(>10%)
- Higher incidence of potential lethal injuries (torso & head) RED TAGS
- Huge public health crisis in the U.S.!!!

Mass shooter MCI

Natural Disaster MCI

Type of Injuries By MCI Event

	Tornado	Hurricane	Flooding	Earthquake	Wildfire
Blunt Trauma	X	X	X	X	
Penetrating Trauma	X	X	X	X	
Burns				X	X
Crush	X			X	
Exacerbation of Chronic Conditions		X		X	
Gastrointestinal Illness		X		X	
Respiratory Impact		X	X	X	X
Submersion Injury		X	X		
Infected/Contaminated Wounds	X	X	X		

FEMA

Natural Disaster planning:

How to Plan for Surgical Needs of Casualties

- Life saving (hemorrhage control, craniotomy): 10% of Red Tag casualties
- Open fractures: 10% of all casualties
- Penetrating eye injuries: 5% of all casualties
- Neurosurgery (Urgent): 10% of all casualties
- Chest surgery: 5% of all casualties
- Oral/Maxillary/facial: 5-10% of all casualties
- Burns: 0-5% of all casualties

FEMA

Type of Physicians By MCI Event

	Tornado	Hurricane	Flooding	Earthquake	Wildfire
Trauma Surgeon	X	X		X	X
General Surgeon	X			X	X
Orthopedic Surgeon	X			X	
Neuro Surgeon	X			X	
Plastic Surgeon	X			X	X
Thoracic Surgeon				X	
Vascular Surgeon	X			X	
Internal Medicine	X	X	X	X	X
Pulmonary	X	X			X
Infectious Disease	X	X	X	X	
Pediatric	X	X	X	X	X
OB/GYN	X	X	X	X	X
Behavioral Health	X	X	X	X	X
Anesthesia	X	X	X	X	X

FEMA

Resources for Natural disaster planning:

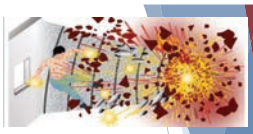
- CDC: Mass Casualty Predictor Model
- HHS:
  - Medical Surge Capacity and Capability: A Management System for Integrating Medical and Health Resources During Large Scale Emergencies
  - Medical Surge Capacity and Capability: The Healthcare Coalition in Emergency response and Recovery
  - Mass Casualty And Mass Effect Incidents: Implications for Health care Organizations

FEMA

https://aspr.hhs.gov/HealthCareReadiness/guidance/MSCC/Pages/default.aspx

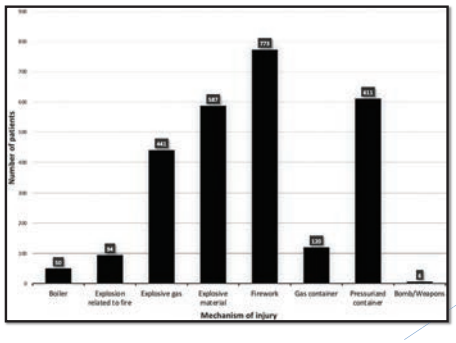
http://www.phe.gov/Preparedness/planning/mscc/Documents/mscctier2jan2010.pdf

Blast MCI



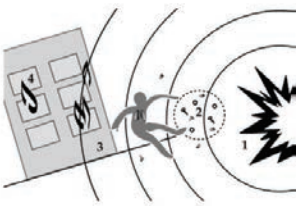
- **Blast** = sudden increase in atmospheric pressure
- **Leading wave** = blast front→ peak pressure, determines primary blast injury
- **Blast pressure** depends on distance from explosion
  - decreased by the r^3 of distance
    - 10ft away receives 8x blast wave as 20ft away
- Negative pressure wave follows (backfilling the vacuum from blast)
  - "mushroom cloud"

Civilian "Blast" Trauma:



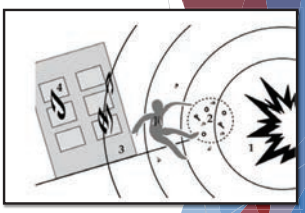
4 types of blast injuries

- Primary: Blast overpressure
- Secondary: Flying debris
- Tertiary: Displacement (victim propelled)
- Quaternary: Misc. (Burn, smoke inhalation, chemical/radiation)



Primary Blast Injuries

- Primary injuries: primarily affect **air-filled organs/cavities**
  - Ear
  - Lung
  - Abdomen
- Radiological diagnosis of primary blast injury focuses on pulmonary and enteric barotrauma
  - pulmonary opacification secondary to diffuse pulmonary alveolar hemorrhage and pneumothorax.
  - enteric injury manifested as intraperitoneal free air on CT
- This blast wave is magnified by the reflection in closed-space explosions



Blast Overpressure (BOP)

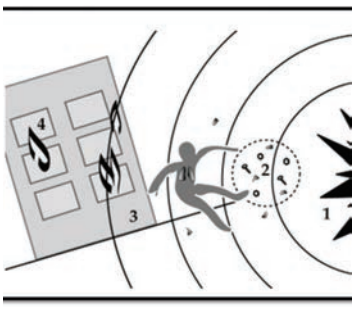
- 3 PSI → knock adult human over
- 15 PSI → TM rupture
- 35 PSI → significant lung injury
- 80 PSI → 50% severe lung injury
- 130 PSI → 50% mortality
- >200 PSI → 100% mortality

Secondary Blast Injury

= Shrapnel

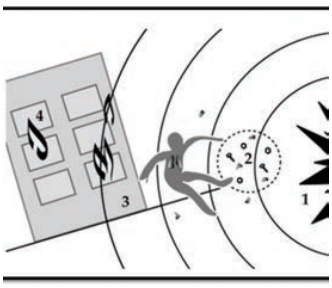
- bomb fragments, objects added to the device to increase lethality primarily penetrating trauma, but may also cause blunt trauma

- Large, irregular pieces, path in body unpredictable
- *"Small holes hide big problems"*
- Vascular injuries require early intervention
- Highest mortality: brain, heart, major vessels



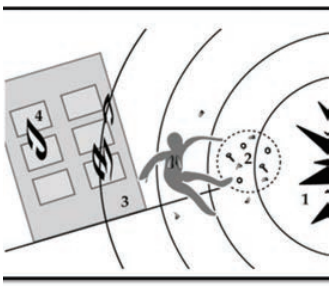
Tertiary Blast Injury

- Victim being thrown by the force of the blast wind
- Mostly blunt trauma
- Fractures: skull, ribs (flail chest), long bones
- Assess for pneumothorax, hemothorax, pulmonary contusion & acute thoracic aortic injury
- Also includes crush injuries:
  - ARF
  - rhabdomyolysis
  - "crush syndrome"



Quaternary Blast Injury

- Burn
- Smoke inhalation/CO poisoning
- Chemical/radiation bombs
- Structural collapse/falling debris



Most clinically challenging aspects of the anesthetic management of blast injury, to include:

Blast-related Lung injury	Blast-induced traumatic airway injury	Hypovolemic shock, coagulopathy	Blast-induced thermal injury.

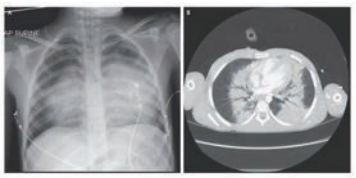
Management of blast injuries

Lung blast injury

- Immediate autonomic response, followed by hemorrhage and parenchymal injury, which then culminates in an inflammatory phase
- Blast pressure disrupts alveolar-capillary interface → alveolar rupture/implosion
  - Blood enters alveoli → pulmonary alveolar hemorrhage
  - Air enters circulation →air emboli
  - Endothelial damage→ platelet/fibrin activation →consumptive coagulopathy, DIC
  - Vagal mediated characteristic triad: apnea, bradycardia and hypotension
  - Other symptoms: tachypnea, dyspnea, cough, hemoptysis, hypoxia
  - 3x worse in closed spaces

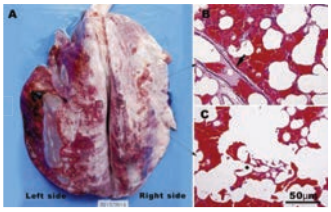
Blast Lung

- "Butterfly" lung on CXR
- Acute arterial air embolism is responsible for most sudden deaths within 1st hour after blast
- Air embolism can affect heart, abdomen, brain, spinal cord



Lung Blast Injury

- Bullae
- Bronchi/alveoli filled with blood broken
- Alveolar septa



Management of blast lung:

- Protective ventilation strategies ~ARDs, avoid high PEEP
- Permissive hypercapnia (except TBI)
- Consider High frequency ventilation
- Consider ECMO

Other organs effected by primary blast:

- Ear: TM rupture #1 injury after blast overpressure incident
- Eye: common ~10% of blasts;
  - abrasions, intraocular hemorrhage, open globe
- Brain: less susceptible to 1º blast injury
  - Cerebral contusion, skull fracture, coup-counter-coup injury
  - Epidural, Subdural bleed, intracranial hemorrhage, edema, CVA related to air or fat emboli
- Cardiac:
  - Contusion, neurocardiac reflexes (brady/hypotension), coronary artery air emboli, arrythmia, Pulmonary HTN 2/2 PBLI
- GI:
  - gastric or intestinal perforation→ peritonitis, sepsis
- Other non-gas containing organs

Blast Airway concerns:

Laryngeal Injuries:

- Laryngeal injury
- Thermal airway injury
- Vocal cord hemorrhage
- Cartilage dislocation
- Laryngeal fracture

Tracheal/Bronchial injuries:

- Difficult intubation
- Laryngotracheal separation/injury (Listen for stridor)
- Pneumothorax & hemothorax
- Subcutaneous emphysema
- Difficult ventilation

- Damage control surgery
- ABC, RSI, avoid N2O
- Treat Pneumothorax
- ARDS ventilation strategies, limiting PEEP
- Air emboli risk for days after
- Expect missed injuries
- Lung isolation may be needed
- Fluids
  - Overload→ ARDS worse, dilutional coagulopathy
  - Suboptimal→ exacerbates tissue damage, AKI (esp crush injury, burn)
  - Transfusion: Ratio & VHA driven, early FFP, platelets, lots of calcium

Anesthetic management of blast injuries

- Blasts have unlimited wounding potential
- Blast injured at risk of under triage
- ABCs
- Triage and re-triage
- Damage Control Surgery
- Leave wounds open, repeat wound vac changes, washouts
- Expect to miss injuries
- Expect many required surgeries

Crush injury

- Compressive force → direct tissue damage, occlusion of venous outflow→ myonecrosis
- "Smiling death" = Clinical deterioration including death can occur within 20 minutes of extrication
- "Crush syndrome"
- Delayed complications and death from renal failure

Traumatic asphyxia

- Severe crush injury to the chest (eg, heavy object, stampede)
  - Cervicofacial cyanosis
  - Facial edema
  - Subconjunctival hemorrhage
  - Petechial eruptions on the face, neck, and torso above crush
- Typically seen after a short duration of crushing forces
- Seen in crowd crush events, such as stampedes at sports, music, and political events
- May be combined with liver and spleen lacerations, rib fractures, pulmonary contusions, and anoxic brain injury

Crush injury mortality

The majority of mortality occurs at the scene due to traumatic asphyxia, severe traumatic brain injury, and severe hemorrhagic shock

"Time under the rubble" is an important determinant of survival

80% victims die immediately due to direct effects of trauma/traumatic asphyxia	10% survive with minor trauma	10% are severely injured • Of those, 40-70 % develop "crush syndrome"

"Crush Syndrome"

- "Crush syndrome" is the 2nd leading cause of mortality in earthquakes
- Extrication time is strongly associated with earthquake-related mortality. Children and older individuals are highly vulnerable.
- Secondary prevention of "crush syndrome" may be possible with timely management at the scene of injury and carried on through field care, prehospital transport, and initial hospital care

"Crush Syndrome"

- Multisystem organ dysfunction, predominantly acute kidney injury, or death
- May present with rhabdomyolysis (hyperkalemia, hyperphosphatemia, and myoglobinuria)
- Nephrotoxic effects of heme products & myoglobin → AKI
- Patients with rhabdomyolysis-induced renal failure have a mortality of ~20%
  - higher in patients with multiple injuries or multiorgan failure and when local resources are overwhelmed

Acute Renal Failure

- Crush injury can be associated with **rapid and severe hyperkalemia**, requiring renal replacement therapy
- MCI events with large numbers of crush injuries → excess demand on ICUs and dialysis resources
- When inadequate numbers of HD machines are available, peritoneal dialysis can be used, despite its slower clearance of potassium

Crush injury treatment:

- Treat hypovolemia, including during extrication if prolonged
- Supportive/ATLS
- Prevent crush syndrome with large volume IV crystalloid
- Amputation restricted to cases where a limb is not salvageable or injuries are causing sepsis or uncontrollable hemorrhage
- No indication for prophylactic fasciotomies, only recommended if acute compartment syndrome develops

Trauma Panel Summary:

- Discussed types of mass casualty events and the importance of having an MCI plan at every hospital
- Described triage tools & alternative anesthetic techniques to be used during mass casualty events or disasters
- Reviewed management of common trauma injuries encountered in during mass casualty events, including blast and crush injuries

Any Questions?

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