Crush Syndrome: Death by Rescue?

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Predictable Course: “Death by Rescue?”

- Patients may survive for days in their entrapment.
- Patients may die shortly after rescue if untreated: “The smiling death.”
- ** Crush Syndrome** is a primary cause of immediate and delayed death among live rescues.
- Patients survive if treated early and aggressively "in the rubble"
Objectives

- Define *crush injury*, *compartment syndrome*, and *crush syndrome*
- Describe pathophysiology of crush injury
- Identify causes of death from crush injury
- Identify potential clinical manifestations of crush syndrome
- Identify how myoglobin indicates diagnosis
Objectives (continued)

- Identify therapeutic modalities
- Describe care of local injury
- Describe management of crush syndrome “in the rubble”
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- The author declares he has not financial interests in any products discussed in this presentation.
Definitions

Direct Mechanical Crush:
- Immediate cellular injury from mechanical disruption of tissue

Crush Injury: (Local Effect)
- Muscle injury from prolonged compression

Compartment Syndrome: (Local Effect)
- Crush injury from tissue swelling within the confines of the fibrous sheath of the muscle compartments

Crush Syndrome: (Systemic Effect)
- Systemic manifestations caused by crushed muscle when released from compression
Muscle Tissue in Compression

- Muscle tissue vulnerable to sustained compression
- Compression from debris or body weight
- Timeframe: 1 to 6 hours
- Amount of muscle tissue
  - Lower extremities
  - Buttocks
  - Entire upper extremity and pectoralis
The Annual Crush Syndrome Challenge
Normal Muscle Cell Function

- Arterial blood provides glucose, O\textsubscript{2}, nutrients
- Cell membranes separate cellular contents and transport electrolytes, glucose, etc.
- Muscle cell uses glucose, O\textsubscript{2}, nutrients to produce energy
- Myoglobin provides rapid O\textsubscript{2} transport within muscle cells
- Capillaries allow efficient transfer of nutrients
- Venous blood removes toxins/waste products
Dysfunction

- Local arterial blood disrupted
- Cells function anaerobically, creating lactic acid
- Cell membrane disrupted—cell disruption and death
- Intracellular contents released into local area
- Local capillaries become leaky
- Re-introduction of $O_2$ may create oxidative toxins
Effects of Crush Injury

- Lactic acid produced
- Potassium and other electrolytes released
- Myoglobin released
- Other toxins created/released (superoxides, free O₂ radicals)
- Uric acid produced
- Capillary leak
- Thromboxane, prostaglandins, and other immune system substances generated
- Muscle cell enzymes released
Effects of Crush Injury (continued)

- Effects are LOCAL ONLY until tissue released and reperfused by blood
- Reason that patients survive entrapment despite severe crush injury
- Adverse systemic processes begin immediately upon tissue release
Effects of Releasing Compressed Tissue: Crush Injury becomes Crush Syndrome

Re-perfusion of crushed area causes systemic effects:

- Capillary Leak >> Hypovolemia/Shock
- Severe Metabolic Acidosis >> V-fib
- Hyperkalemia >> Arrhythmia / Asystole
- Myoglobin/Uric Acid/Toxins >> Kidney Failure
- Other toxins: lung/liver/renal injuries
Cause of Death

- **Major**
  - Hypovolemia
  - Dysrhythmia
  - Renal failure

- **Other**
  - Adult Respiratory Distress Syndrome (ARDS)
  - Sepsis
  - Other electrolyte disturbances
  - Ischemic tissue infection (gangrene)
Potential Clinical Findings

- **Pre-release of entrapment:**
  - Painless crushed extremity (hypesthesia/anesthesia)
  - Distal pulses may or may not be present

- **Post-release of entrapment:**
  - Agitation
  - Continued hypesthesia/anesthesia
  - Severe pain in crushed extremity
  - Muscle function decreased/absent
  - Progressive swelling of injured area
  - Systemic problems
Crush Syndrome Diagnosis

- Prolonged muscle mass compression or entrapment
- Identifying potential crush mechanism
- Looking EKG changes
- Determining presence of urinary myoglobin post-release
EKG Abnormalities

- Related to primarily to
  - Potassium levels and rate of rise
  - Acidosis
- Peaked T-waves, AV blocks, widened QRS, sine wave
- Responds rapidly to effective intervention
**ECG Pattern of Hyperkalemia**

- **Tall T wave**
- **Prolonged QRS**
- **Long PR interval**

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**Hyperkalemia**

- **K = 6.0-7.0 mEq/L**
  - "tented" T wave

- **K = 7.0-8.0 mEq/L**
  - QRS widening

- **K = 8.0-9.0 mEq/L**
  - PR interval lengthening

- **K = 9.0-10.0 mEq/L**
  - Atrial arrest

- **K > 10 mEq/L**
  - R.I.P.
Serum potassium levels

A. normal (3.5 - 5.0 mEq/L)
B. about 7.0 mEq/L
C. 8.0 - 9.0 mEq/L
D. >10.0 mEq/L

Changes in the ECG in lead II caused by hyperkalemia
Myoglobin (continued)

- Myoglobin
  - Solubility in urine: 50 mg myoglobin/ml urine

<table>
<thead>
<tr>
<th>Urine pH</th>
<th>% Precipitated</th>
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</thead>
<tbody>
<tr>
<td>8.5 to 7.5</td>
<td>0%</td>
</tr>
<tr>
<td>6.5</td>
<td>4%</td>
</tr>
<tr>
<td>5.5</td>
<td>23%</td>
</tr>
<tr>
<td>5.0</td>
<td>46%</td>
</tr>
<tr>
<td>&lt;5.0</td>
<td>73%</td>
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</table>
Hyperkalemia and Acidosis

- Sodium bicarbonate
- Glucose + insulin (requires careful monitoring)
- Beta-2-selective catacholamines
- Calcium (for life-threatening dysrhythmias)
- Others (Kaexololate/Lasix/dialysis)
- Follow patient and cardiac monitor parameters
# Adult Treatment of Acute Hyperkalemia

<table>
<thead>
<tr>
<th>Drug</th>
<th>Action</th>
<th>Dose</th>
<th>Onset</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Chloride</td>
<td>Protects heart</td>
<td>10% 5-10 mL iv</td>
<td>1-5 min</td>
<td>30-60 min</td>
</tr>
<tr>
<td>NaHCO3, if acidotic</td>
<td>Antagonism/Redistributes</td>
<td>44-88 mEq iv</td>
<td>5-10 min</td>
<td>15-30 min</td>
</tr>
<tr>
<td>Glucose &amp; Insulin</td>
<td>Shifts into cells</td>
<td>D50 50cc + regular insulin 10 Units</td>
<td>10-20 min</td>
<td>4-6 hrs</td>
</tr>
<tr>
<td>Albuterol</td>
<td>Shifts into cells</td>
<td>5-20mg Neb</td>
<td>30 min</td>
<td>2-3 hrs</td>
</tr>
</tbody>
</table>
## Field Treatment

1. Basic airway/spinal immobilization prn/control major bleeding
2. Oxygen
3. Advanced airway prn
4. Cardiac monitor/document rhythm and attach EKG strip
5. Venous access

### Note:

## CRUSH INJURY

6. If wheezing, **albuterol 5mg** via hand-held nebulizer

7. Fluid resuscitate prior to releasing compression

8. Consider **morphine 2-20 mg**

9. Release compression and extricate patient

10. Treat injuries by appropriate trauma guideline

## CRUSH SYNDROME

### Note:

6. Fluid resuscitate prior to releasing compression

7. **Albuterol 5mg** via continuous mask nebulization

8. **Calcium chloride 1 gm** slow IVP over 60 seconds

9. **Sodium bicarbonate 1mEq/kg** added to first liter of NS, IV, wide open

10. Consider **morphine 2-20mg IVP.**

11. Release compression and extricate

12. Treat injuries by appropriate trauma guideline

## Drug Considerations

### Albuterol:

1. Pediatrics: see Color Code Drug Doses/L.A. County Kids

### Normal saline:

2. 20ml/kg for all ages

### Morphine:

3. Alternate routes: 10mg IM one time
4. Maximum adult dose: 20mg.
5. Use with caution if BP<100 systolic, altered LOC or respiratory depression.
6. Not recommended if signs of major system injury
7. Pediatrics: 0.1mg/kg IVP/IM one time.

### Calcium Chloride:

8. Precipitates with sodium bicarb-flush tubing before bicarb infusion.

### Special Considerations

1. Treatment may be compromised by confined space or MCI situation. Ideally start treatment prior to release of compression. Limb amputation by MD may be necessary.

2. Entrapment lasting > than 4 hours or suspicion of hyperkalemia:
   - Peaked T waves
   - Absent P waves
   - Widened QRS complexes

3. Hydrate prior to release of compressive force to combat hypovolemia and to dilute cellular toxins.
Renal Injury

- Maximize renal perfusion
  - IV normal saline
- Diuresis (brisk urine flow, goal of 300cc/hr)
- Careful alkalinization of urine (pH > 6.5)
  - Sodium bicarbonate
- Monitor urine flow and pH (Bladder catheterization if possible)
Other Treatment Options

- Oxygen/airway support
- Mannitol (lower dose than for ICP control)
  - Diuresis, volume expansion, and possibly free radical scavenging
- Renal dose dopamine
Prolonged Treatment Model

- NS 1 liter/hr (15ml/kg/hr) while in rubble
- ½ NS 1 liter/hr (15ml/kg/hr) with 50 mEq sodium bicarbonate to each second or third liter (total of 200-300 mEq/day) after rescue
- Add 50 ml 20% mannitol (1-2g/d), if urine output over 20 ml/hr
- Goal is urine output of 300 ml/hr
- Requires up to 12 liter/day iv fluid and 4-6 amps bicarbonate

Ref: Severe, et.al. NEJM, 354:10, March 9, 2006
Care of the Local Injury

- Protect open wounds
- Splint limb (non-compressive dressing)
- Maintain limb at heart level
- Pain control
- Monitor limb (distal perfusion)
- Irrigation, dressing, hydration
Care in the Rubble Pile

- Providing care while the victim is being extricated
- Patient stabilization
- Treatment of crush syndrome
- Integrating care into the rescue
Crush Injury/Syndrome Extended Scope Guideline
Updated: 4 April 2010  Author: Steven Chin MD, CA TF-2
1. Scene safety: Utilities, LCES, Atmosphere, Other hazards
2. ABC’s:
   - Minimum of dusk mask, advanced as needed
   - Consider albuterol nebulizer for dusk impaction
3. C-spine as needed. Try to clear clinically
4. Cardiac monitor and document EKG strip
5. Venous access and hydrate, if no IV, consider IO, oral or subcutaneous.
6. Assess for crush injury/syndrome:
   If possible crush or impending crush:
7. Albuterol 5mg neb
8. IV/IO/SQ NS 20cc/kg bolus (if unable then consider oral hydration)
   a. if elderly or cardiac consider 250-500cc bolus and reassess for CHF or improvement after each bolus
   b. repeat boluses until fully hydrated, i.e improved mentation, HR < 100, normal BP, urinating, etc.
9. Assess EKG for signs of hyperkalemia
   a. If normal EKG: give 1meQ/kg(1 amp) of Sodium Bicarbonate
   b. If peak T’s: give 1meQ/kg(1amp) Sodium Bicarbonate and D50 50cc (and insulin 10units regular if available...call for medical support)
   c. If widened QRS, no P’s, V-Tach, V-fib, PEA or asystole: give calcium chloride 1gm iv, sodium bicarbonate 1-2meq/Kg(1-2amps) iv and D50 50cc (and insulin 10 units regular if available)
   d. Reassess EKG and patient: may need to repeat above
10. Prior to release of compression:
   a. Ensure fully hydrated
   b. Give additional NS bolus prior to lift
   c. Give additional Sodium Bicarbonate prior to lift
   d. Tape additional ampoule of Calcium Chloride to patient or iv bag
Crush Syndrome Treatment for Dummies

1. Hydrate til to pee clear or get CHF.
2. Anticipate hyperkalemia
Management “in the Rubble”

- Scene Safety: “LCES”
- Provide ABC’s
- Protect airway: dusk mask
- Hypothermia protection
- Provide psychological support
- Hydrate
- Assess for crush injury potential
Management “in the Rubble” (continued)

- If crush potential is identified
  - Establish IV or IO access
  - Fluid replacement prior to extrication
  - Consider pre-alkalinizing
  - Cardiac monitor (run baseline strip)
Management “in the Rubble” (continued)

- If crush potential is identified
  - Before extrication: Hydrate and Alkalinize: give at least 1-2 liters NS iv with 50meQ/L sodium bicarbonate

- If signs of hyperkalemia
  - Albuterol by neb or MDI
  - D50 (and insulin, if available.)
  - Calcium Chloride, if widen QRS.
Management “in the Rubble” (continued)

- Be prepared during extrication to treat
  - Hypovolemia: extra iv bags nearby
  - Acidosis: bicarbonate nearby
  - Hyperkalemia: i.e. calcium ampoule taped to iv bag or immediately available
  - Monitor rhythm strip
Arterial Tourniquets

- Indications
  - Patient in extremis, bleeding resistant to direct pressure and elevation (when possible)
  - Need for rapid extrication

- Complications
  - Inadequate analgesia
  - Must monitor closely to prevent unintended release
  - Increases injury to local tissue
Alternative Methods of Hydration

- Oral
- Subcutaneous
  - Hypodermoclysis: the infusion of fluids into the subcutaneous tissue
Prolonged Incident Stress

Rescuers and field medical providers have additional psychological stressors including:

- Prolonged contact time with victim
- Exposure to significant physical risk to rescuers
- Need to make critical decision in an austere environment
Disaster Personal Preparedness

- Create an emergency communications plan:
  - Pre-determined out-of-state contact
- Establish a meeting place, if you can’t go home
- Assemble a disaster supply kit:
  - Food, water, first aid, personal medications, clothing, etc.
  - Flashlight, battery powered radio, cell phone/battery
  - Cash, copies of important documents
- Check on school’s emergency plan of any children you have

(adapted from TERRORISM: Preparing for the Unexpected, American Red Cross)
Summary: Preventing Death by Rescue

- Anticipate Crush Syndrome
- Begin treatment “in the hole” before extrication
- Hydrate and alkalinize to maintain renal output
- Expect to treat hypotension and hyperkalemia / acidosis