Case Presentation

• Called to isolated logging road

• MVC: logging truck vs tree
Arrival to Scene

Logging Truck vs Tree

- 57 y/o male
- Type of Crash: Truck vs tree
- Speed: high speed
- Position in car: Driver
- Restraints: lap belt
- Interior-exterior damage: significant
Logging Truck vs Tree

• A quick size-up of scene
• Alert, O x 4, denies LOC

• Both legs pinned under dash board.
• No uncontrolled bleeding seen
• Complex and potentially lengthy extrication will be needed.
Objectives

- Define crush injury and crush syndrome.
- Discuss the pathophysiology of crush syndrome.
- Describe pre and post extrication treatment in the prehospital setting.
Lecture Overview

• Epidemiology
• Definitions
• Pathophysiology
• Treatment
Mortality Impacted By

• Severity of crush injury.
• Timing of treatment.
• *Pre-extrication treatment provided.*
Introduction

• Providing rapid, aggressive treatment prior to extrication may make the difference between life and death.
Introduction
Historical Perspective

• First recorded in bombing of London during WWII by Bywaters and Beall in 1941.
• 5 patients pulled from rubble with crush injuries.
• Presented with swollen extremities and dark urine.
• Later died of renal failure.
• Postmortem examination revealed muscle necrosis and brown pigment casts in the renal tubules.
Introduction

• Many etiologies
Trauma Related Causes

- Natural disasters such as earthquakes
- Terrorist attacks and during Wars times
- Buildings collapsed
- Industrial incidents such as mining accidents
- Motor Vehicle Crashes
1999 Marmara earthquake
Nimitz Freeway (Interstate highway I-880) collapse in Oakland California from October 1989 earthquake, causing 42 deaths
Car crushed by 1989 Nimitz Freeway collapse; one patient rescued here on the fifth day later died from complications of crush syndrome.
Pedestrian bridge collapse at university in Miami.
3-15-18
Four explosions killed 43 men, in what is considered New Zealand’s worst mining disaster.
Non-Trauma Related Causes

- Immobility against firm surface for > one hour.

- Own body becomes source of tissue compression. (torso lying on a leg)
Non-Trauma Related Causes Found Down

- Intoxication
- After assault
- Elderly with hip fx
- Carbon monoxide poisoning

- Stroke/CVA
- Drug OD
- MAST pants
Definition Crush Injury

• Injury caused as a result of direct physical crushing of the muscles due to something heavy.

• Direct injury resulting from the crush.

• Typically involves legs, arms and trunk.
Crush Syndrome Definition

- Systemic manifestation of muscle damage resulting from pressure or crushing.

- Systemic manifestation of breakdown of muscle cells with release of their contents into the circulation, resulting in metabolic derangements and acute renal failure.
Crush Syndrome

Synonyms

• Traumatic rhabdomyolysis
• Bywaters’ syndrome
Crush Syndrome

- Crush syndrome can occur in crush scenarios of less than 1 hour.

- Generally over 4 hours
Pathophysiology

• Compression force damages cell in immediate area.
• Continued pressure decreases circulation to the area and cells begin to switch to anaerobic metabolism due to decreased $O_2$ supply.
• Cells begin to leak their contents into the surrounding tissues.
• Once force is released, toxic substances are released into the systemic circulation.
Extracellular Fluid Shifts

Limb Compression

- Direct Pressure to cells
- Muscle Cells Rupture
- Compression Of Large Vessels

Release of toxins from Cells
Muscle Ischemia
Muscle Infarction

Extracellular Fluid Shifts

ARF

Myoglobinemia

SHOCK

Acidosis & Hyperkalemia

Cardiac Dysrhythmias
**Pathophysiology**

- Damaged muscle tissue produces and releases toxins that have detrimental effects on body.

<table>
<thead>
<tr>
<th>Toxin</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histamine</td>
<td>vasodilation and bronchoconstriction</td>
</tr>
<tr>
<td>Lactic Acid</td>
<td>Acid metabolic acidosis and cardiac dysrhythmias</td>
</tr>
<tr>
<td>Nitric Oxide</td>
<td>vasodilation, which worsens hypovolemic shock</td>
</tr>
<tr>
<td>Potassium</td>
<td>hyperkalemia</td>
</tr>
<tr>
<td>Thromboplastin</td>
<td>disseminated intravascular coagulation</td>
</tr>
</tbody>
</table>
Pathophysiology
Metabolic Derangements

• Hypovolemia: fluid in damaged muscle
• Hyperkalemia: $K^+$ is released from cells
• Hypocalcemia: calcium flows into muscle cells (leaky cell membranes).
• Metabolic acidosis: due to lactic acid release from ischemic muscle.
• Hyperphosphatemia
Post-Extrication Reperfusion Syndrome

- Sudden release of crushed extremity.
- Results in:
  - acute hypovolemia
  - metabolic derangements
  - at risk for renal failure (release of myoglobin)
Suspect Crush Syndrome

• Large amount of muscle mass involved.

• Prolonged time of compression.

• Compromised blood flow.
Signs and Symptoms

- Skin: bruised and discolored
- Pulses: may or may not be present
- Swelling: usually appears rapidly once pressure is released.
- Pain: may become severe after pressure release.
- Maintain high index of suspicion.
Treatment

• Pre-extrication

• Post-extrication
3 Killers of Crush Syndrome

- Hypovolemic shock
- Life-threatening dysrhythmias (hyperkalemia)
- Acute renal failure
Pre-Extrication
Pre-extrication

• Rescue safety is the first priority.

• Airway and C-spine.

• Breathing: high flow oxygen if hypoxic

• Circulation: stop bleeding, IV or IO placement, splint limbs.
Pre-extrication

• Cardiac monitor
• Establish IV/IO access- 2 large bore
• Start fluid replacement prior to extrication.
• Pain control
Pre-extrication Fluid Resuscitation

- Aggressive fluid resuscitation.
- Critical to protect kidneys and prevent RF.
- Warm Crystalloid without $K^+$ (no LR).
- Warm blood if indicated.
- Suggested to start at 1 - 2 liters NS.
- Continue at rate of 1 - 1.5 L/hr.
- Adjust rated depending on clinical status.
Airlift Northwest Blood Products

- 2 units O- pRBC’s
- 2 units of liquid plasma
Buddy Lite Warmer

• Use for fluids and blood
  - crystalloid flow rate: 80 cc/hr
  - packed RBC: 50 cc/hr

• Goal temperature is 38° C +/- 2° C
Sodium Bicarbonate
Prior to Release of Compression

- Administer prior to release of compression.
- 1 mEq/kg sodium bicarbonate (50-100 mEq 8.4%).
- May add to IVF’s.
- Helps to treat hyperkalemia and acidosis.
- Alkalinizes the urine (protect against ARF).
  - reduces urine cast formation
  - diminishes toxic effects of myoglobin
Hyperkalemia

• Prophylaxis is common in prehospital setting.
• Primary treatment: sodium bicarbonate
• May use of calcium gluconate or calcium chloride as cardioprotective measures.
# Hyperkalemia

## ECG Changes

<table>
<thead>
<tr>
<th>Serum potassium</th>
<th>Typical ECG appearance</th>
<th>Possible ECG abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild (5.5-6.5 mEq/L)</td>
<td>![ECG Image]</td>
<td>- Peaked T waves</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Prolonged PR segment</td>
</tr>
<tr>
<td>Moderate (6.5-8.0 mEq/L)</td>
<td>![ECG Image]</td>
<td>- Loss of P wave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Prolonged QRS complex</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- ST-segment elevation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ectopic beats and escape rhythms</td>
</tr>
<tr>
<td>Severe (&gt;8.0 mEq/L)</td>
<td>![ECG Image]</td>
<td>- Progressive widening of QRS complex</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Sine wave</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Ventricular fibrillation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Asystole</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Axis deviations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Bundle branch blocks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Fascicular blocks</td>
</tr>
</tbody>
</table>
Hyperkalemia
Sine Wave Pattern in Severe Hyperkalemia
# Treatment of Hyperkalemia

<table>
<thead>
<tr>
<th>Treatment of hyperkalemia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Antagonism of membrane actions of potassium</strong></td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td><strong>Shifts K</strong></td>
</tr>
<tr>
<td>Drive extracellular potassium into the cells</td>
</tr>
<tr>
<td>Insulin and glucose</td>
</tr>
<tr>
<td>Sodium bicarbonate, primarily if metabolic acidosis</td>
</tr>
<tr>
<td>β2-adrenergic agonists</td>
</tr>
<tr>
<td><strong>Eliminates K</strong></td>
</tr>
<tr>
<td>Removal of potassium from the body</td>
</tr>
<tr>
<td>Loop or thiazide diuretics</td>
</tr>
<tr>
<td>Cation exchange resin</td>
</tr>
<tr>
<td>Dialysis, preferably hemodialysis if severe</td>
</tr>
</tbody>
</table>

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Pre-Extrication Treatment

Mannitol

- Osmotic diuretic
- Use to maintain diuresis
- Likely helpful if inadequate U/O
- Not generally available in the field
- Usually not needed during pre-hospital time.
If Unable to Pretreat

- Consider tourniquets to crushed limbs until fluids initiated.
Pre-Extrication Use of Tourniquets

• Apply to proximal, unentrappeportion of pinned extremity.
• Delays release of acidotic, $K^+$ infused blood as long as tourniquet in place.
• Allows for stabilization of other injuries.
• Release tourniquet in more controlled in-hospital or OR settings.
Post-Extrication
WATCH OUT
Post-extrication Reperfusion Syndrome

- Sudden release of crushed extremity.

- Results in:
  - acute hypovolemia
  - metabolic derangements (↑ $K^+$)
  - at risk for renal failure (release of myoglobin)
Post-extrication

- Monitor and treat ABC’s.
- Avoid succinylcholine.
- Avoid LR (K⁺).
- Prepare to treat hypovolemic shock.
- Prepare to treat hyperkalemia.
- Rapid transport to definitive care.
Emergency Treatment of Severe Hyperkalemia

- **Calcium:**
  - 5-10 cc 10% calcium chloride IV over 2-5 mins.
  - 15-30 cc 10% calcium gluconate over 2-5 mins

- **Sodium Bicarb:** 1mEq/kg up to 100 mEq IVP

- **Albuterol:** 10-20 mg over 15 minutes

- **1 amp $D_{50}W$ (25 gms) + 10 units reg insulin IV**
Back to Our Case
Arrival to Scene

Quick Size-Up of Scene

• 57 y/o male, 250 lb
• High speed, logging truck vs tree
• Restrained driver
• Both legs trapped under dash
• No uncontrolled bleeding seen.
• Anticipate complex and lengthy extrication.
What Injuries Might You Suspect?
What Injuries Might You Suspect?

• A & B problems: Chest Injuries
• C problems: Shock- bleeding
• Lower extremity injuries
• Crush injury- entrapment (legs)
Pre-Extrication ABC’s

- A = talking, slightly anxious
- B = SOB, BS equal
- C = has a pulse
- D = orientated x 4, remembers event

Vital signs:
- BP - 90/p
- HR - 120
- RR - 25, shallow
What Should We Do Now?
3 Killers of Crush Syndrome

- Hypovolemic shock
- Life-threatening dysrhythmias (hyperkalemia)
- Acute renal failure
Pre-Extrication Treatment

- High flow oxygen
- Continuous ECG monitoring
- Large bore IV/IO x 2
- What type of fluid?
  - Fluid warmer (buddy lite)
- Pre-treat with Sodium Bicarb
Post-Extrication

• Put on BB/CC
• Put into back of rig
• Alert, talking
• C/O difficulty catching his breath, and lower extremity pain.
Before you can do anything:

• He stops talking
• Becomes unresponsive
• Color is ashen, skin cool
Case Continues

- Check pulse: no pulse
- This is what monitor shows

PEA
OH !#&^*@#$

Now What?
General Management PEA

• High-Quality CPR
• Vasopressor (EPI Q 3-5 mins)
• Early identification and rapid reversal of underlying cause(s).
Most Common Causes of Traumatic PEA Arrest

5 H’s
- Hypovolemia
- Hypoxia
- Hydrogen Ion (acidosis)
- Hyper/Hypokalemia
- Hypothermia

5 T’s
- Tablets
- Tamponade (cardiac)
- Tension PTX
- Thrombosis (coronary)
- Thrombosis (pulmonary)
Based on History and Physical Findings What Might Be Going On?

- Crush Injury: **HYPERKALEMIA**
Now what?
Case Continues

- Intubated easily
- Hi-quality CPR
- Epi Q 3 minutes
- Given 2 liters of NS
Case Continues

• **Calcium:**
  - 5 - 10 cc 10% calcium chloride IV over 2-5 mins

• **Sodium Bicarb:** 50 - 100 mEq IV

• **Albuterol:** (2.5 mg in 3cc).
  - 10-20 mg over 15 minutes
End of Case

- On-going CPR and resuscitation for 6 minutes with ROSC.

- Transported to Trauma Center.
Summary
Crush Injury Protocol

Pre-Extrication

- Continuous ECG monitoring
- Establish 2 large bore IV’s or IO with NS
- Pain control: MS, fentanyl, ketamine
- Sodium bicarbonate:
  - 1mEq/kg up to 100 mEq IVP
- Consider tourniquet prior to extrication
Crush Injury Protocol
Post-Extrication

• Continuous ECG monitoring
• Assess for hyperkalemia
• Be ready to treat:
  - hypovolemic shock
  - hyperkalemia
Take Home Messages

• Rapid, aggressive treatment prior to extrication may make the difference between life and death.

• Anticipate and prevent complications.
Take Home Messages

• High index of suspicion.
• On scene treatment is import.
• Aggressive fluid treatment.
• Anticipate hyperkalemia.
• Be prepared for cardiac arrest.