Initial Management of Crush Injuries

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I Need Coffee!

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.

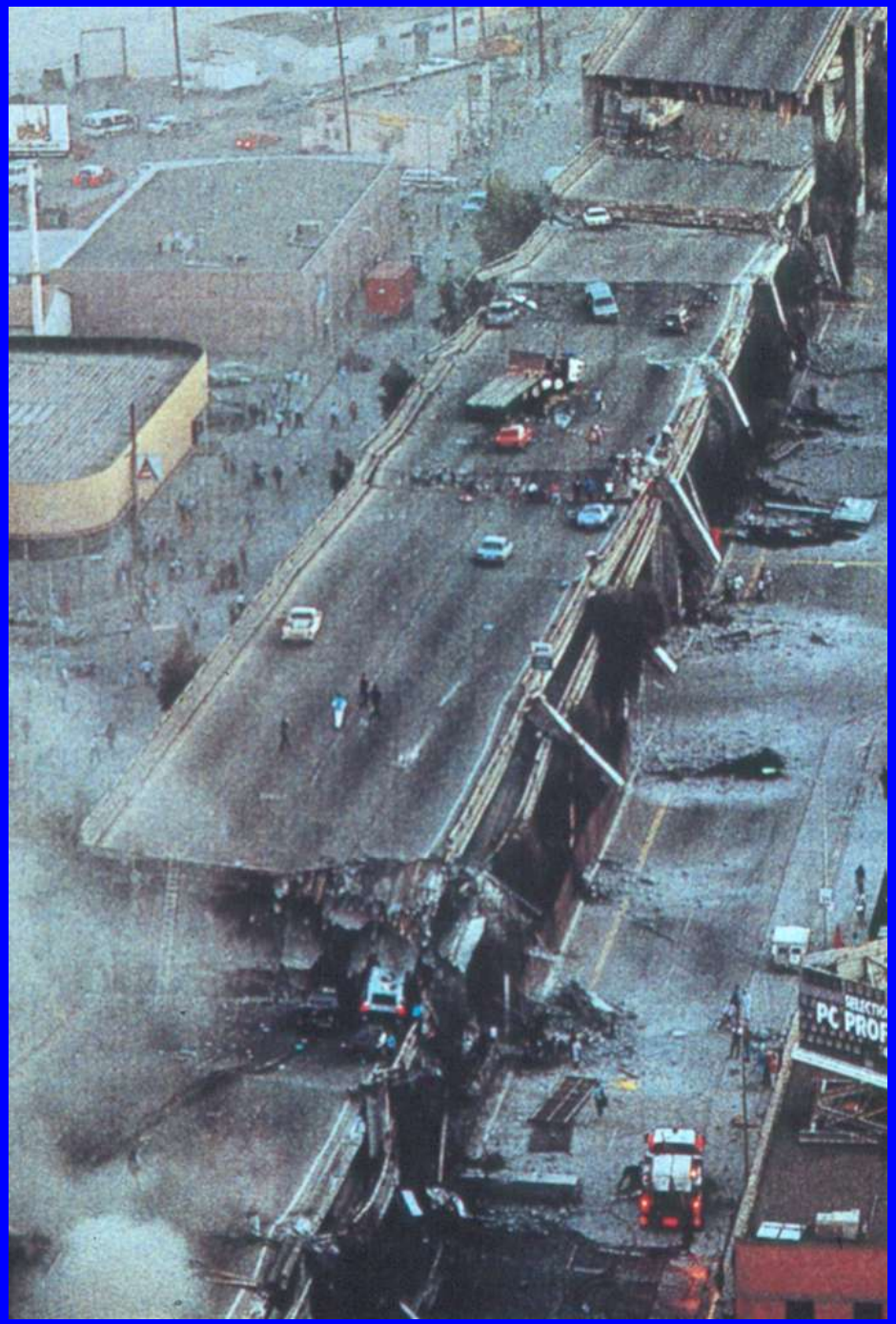
Introduction

- 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

DEFINITIONS

Definition Crush Injury

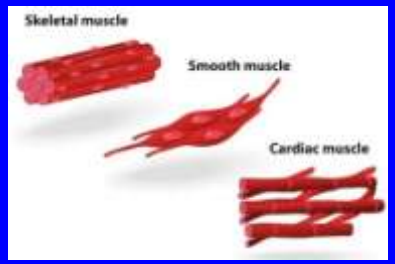
- Injury caused as a result of direct physical crushing of the muscles due to something heavy.

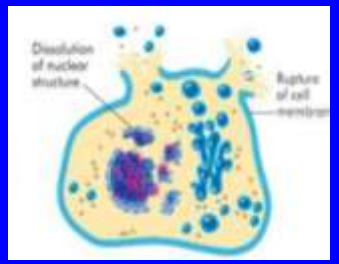
- Direct injury resulting from the crush.
- Typically involves legs, arms and trunk.

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

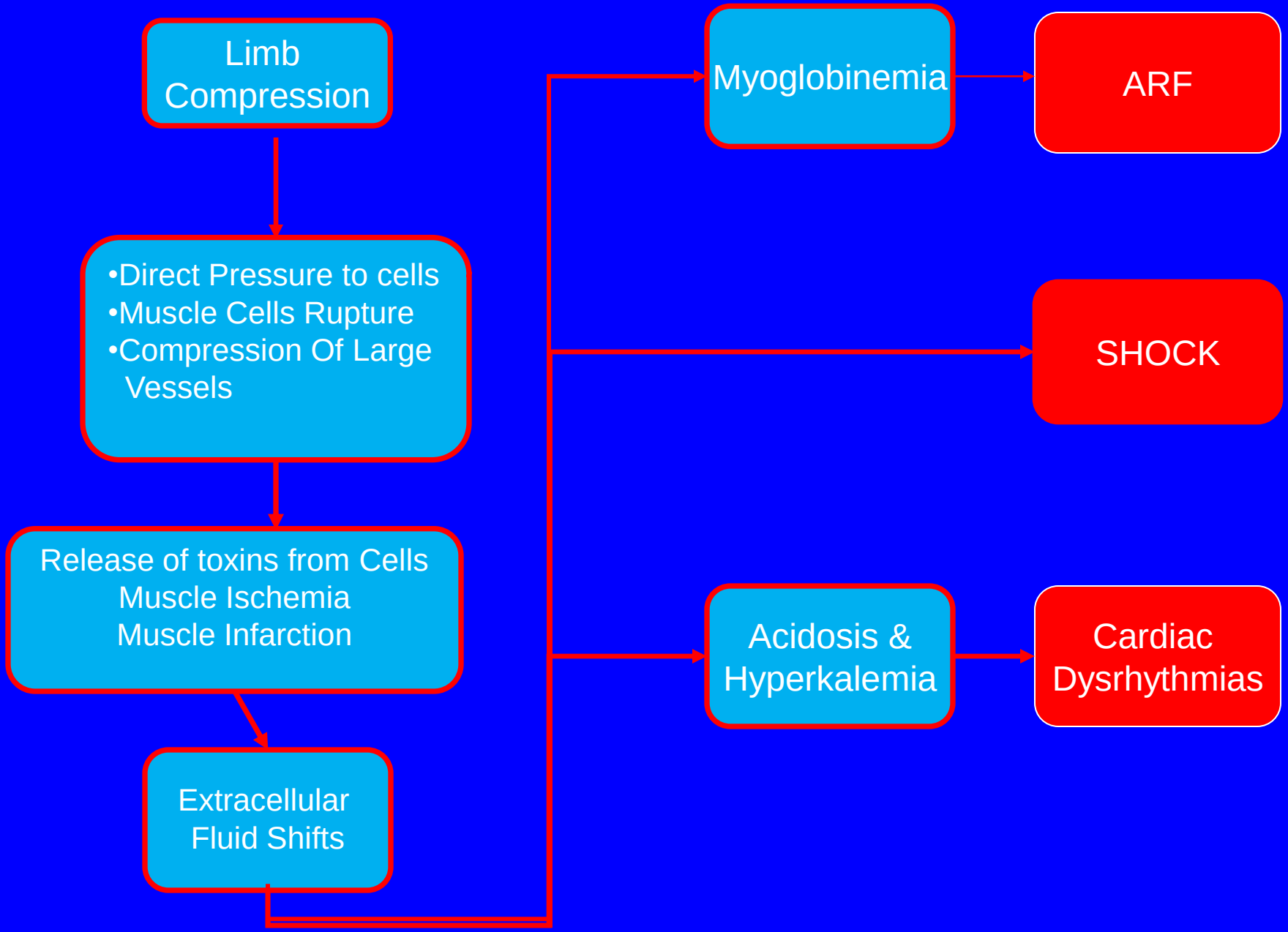
Crush Syndrome

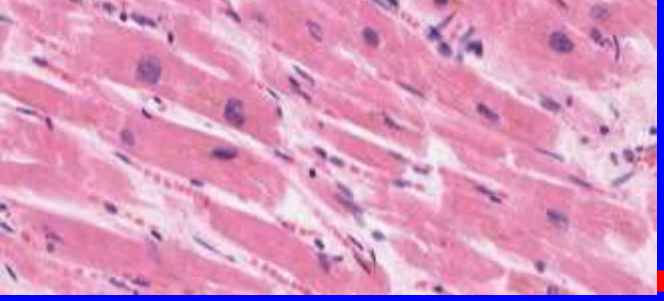
- Crush syndrome can occur in crush scenarios of less than 1 hour.

- 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.


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
Myoglobinemia
ARF
SHOCK
Acidosis & Hyperkalemia
Cardiac Dysrhythmias



Pathophysiology

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

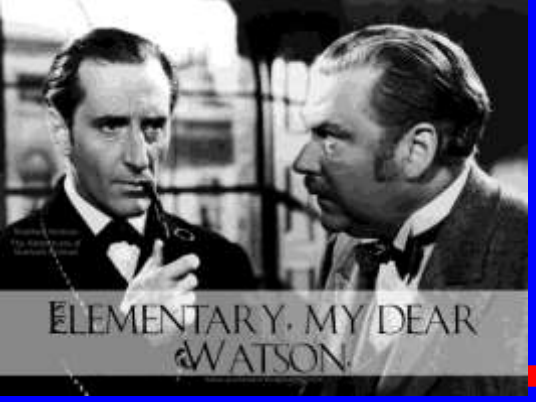
Toxin	Effects
Histamine	vasodilation and bronchoconstriction
Lactic Acid	Acid metabolic acidosis and cardiac dysrhythmias
Nitric Oxide	vasodilation, which worsens hypovolemic shock
Potassium	hyperkalemia
Thromboplastin	disseminated intravascular coagulation

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.

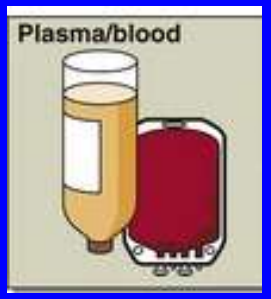
- Airway and C-spine.
- Breathing: high flow oxygen if hypoxic
- Circulation: stop bleeding, IV or IO placement, splint limbs.

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).

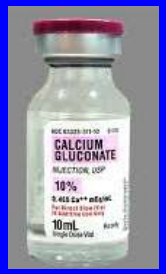
  -reduces urine cast formation

  -diminishes toxic effects of myoglobin

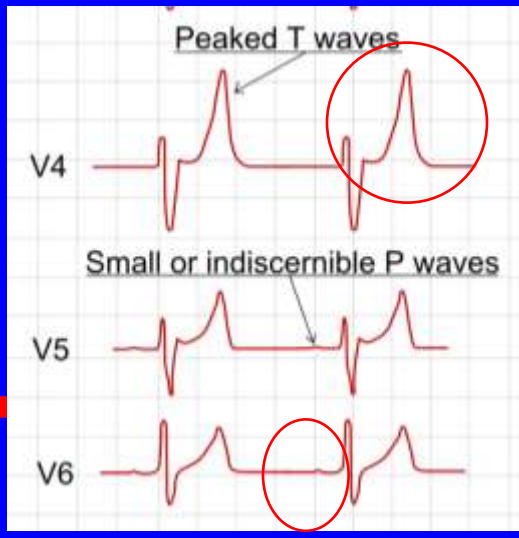
Hyperkalemia

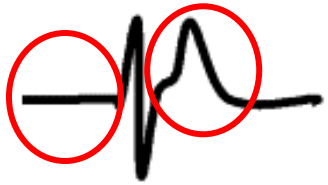
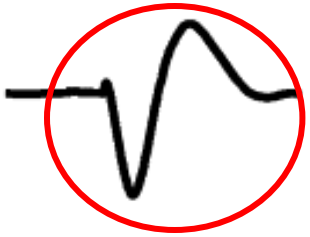
- Prophylaxis is common in prehospital setting.
- Primary treatment: sodium bicarbonate

- May use of calcium gluconate or calcium chloride as cardioprotective measures.

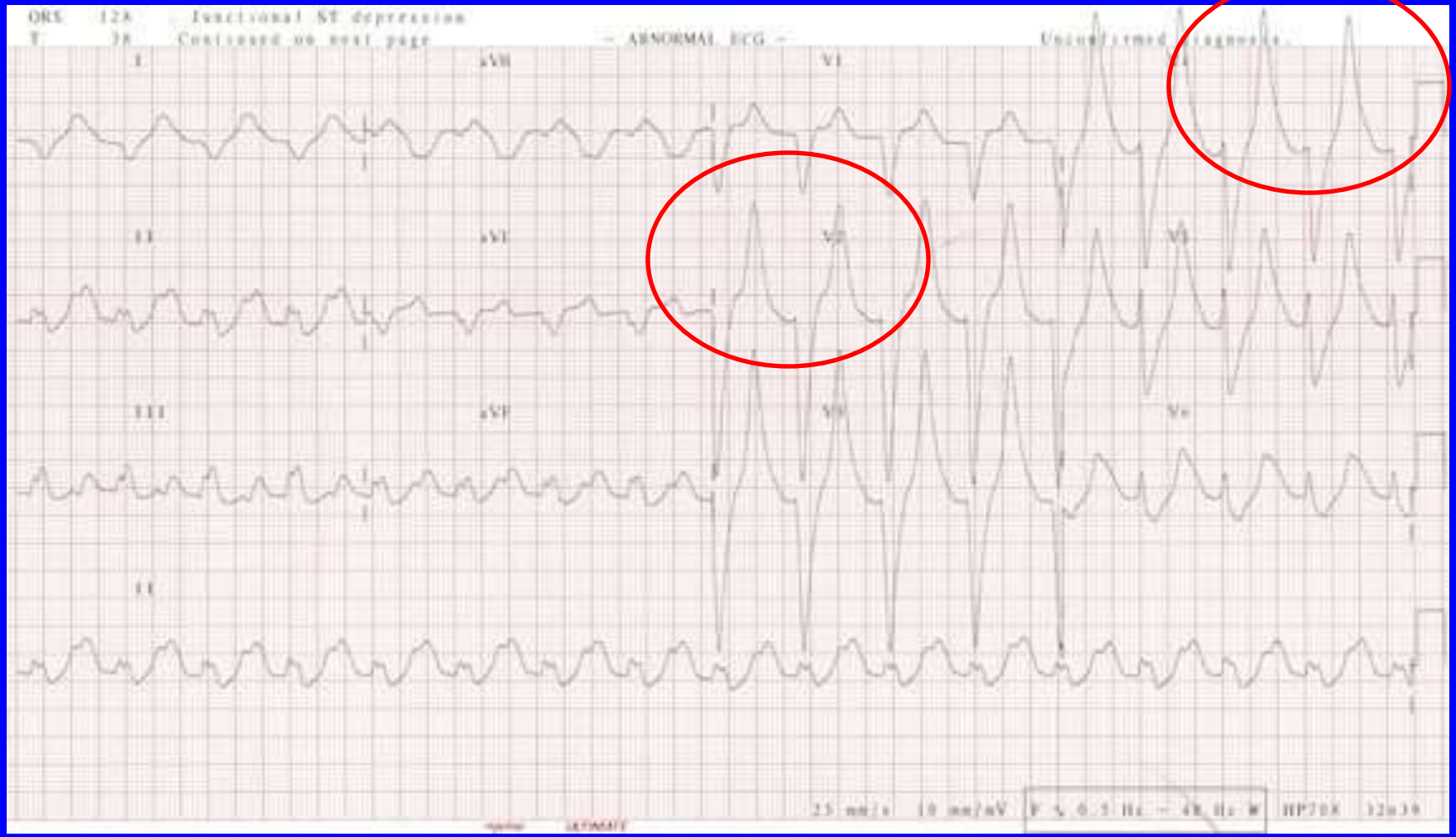


Hyperkalemia ECG Changes



Serum potassium	Typical ECG appearance	Possible ECG abnormalities
Mild (5.5-6.5 mEq/L)		Peaked T waves Prolonged PR segment
Moderate (6.5-8.0 mEq/L)		Loss of P wave Prolonged QRS complex ST-segment elevation Ectopic beats and escape rhythms
Severe (>8.0 mEq/L)		Progressive widening of QRS complex Sine wave Ventricular fibrillation Asystole Axis deviations Bundle branch blocks Fascicular blocks

Hyperkalemia



Sine Wave Pattern in Severe Hyperkalemia

Treatment of Hyperkalemia

Antagonizes K

Shifts K

Eliminates K

Treatment of hyperkalemia

Antagonism of membrane actions of potassium
Calcium **(Calcium chloride 500mg-1gm IV over 2 minutes)**
Drive extracellular potassium into the cells
Insulin and glucose
Sodium bicarbonate, primarily if metabolic acidosis
β2-adrenergic agonists **(Albuterol)**
Removal of potassium from the body
Loop or thiazide diuretics
Cation exchange resin
Dialysis, preferably hemodialysis if severe

UpToDate®

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, unentrapped portion 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

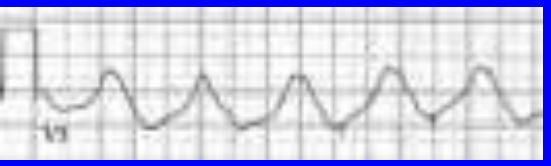
Post-extrication
Reperfusion Syndrome

- 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.

Be Safe Out There……