

Crush-Related Injuries in Earthquakes



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Earthquakes cause blunt trauma

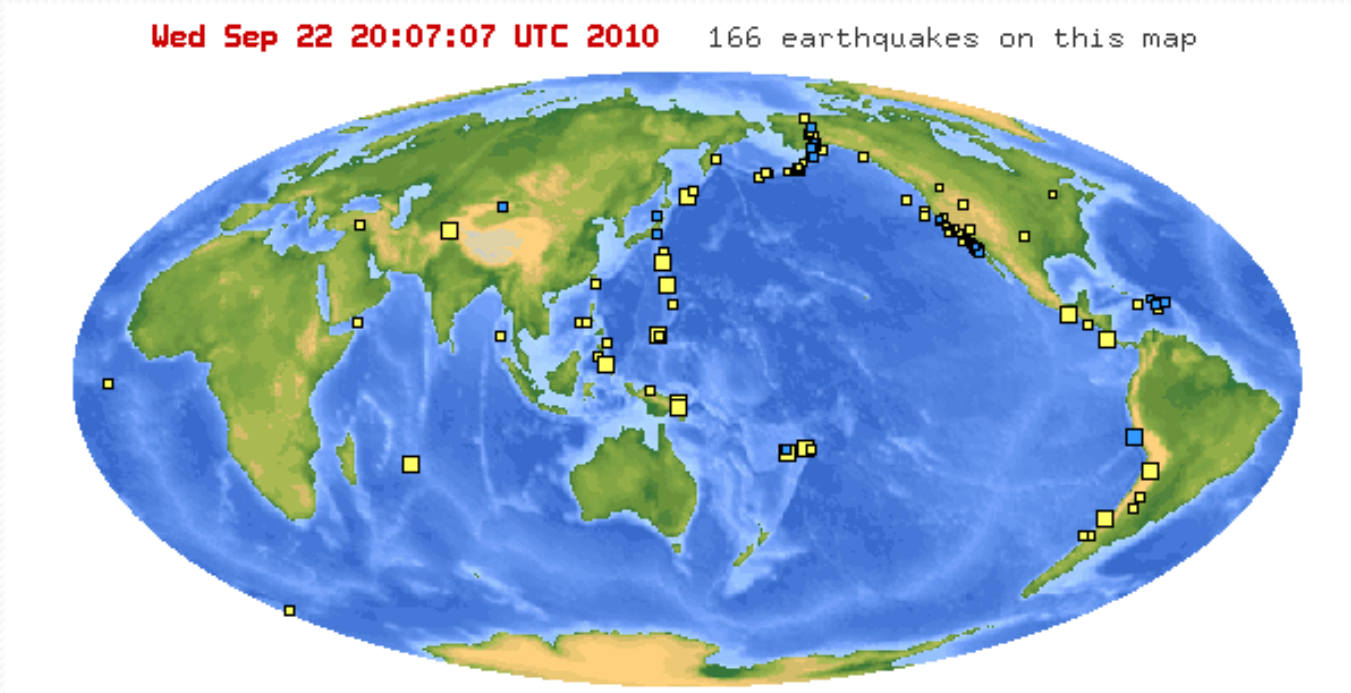


Earthquakes change lives through disability



Earthquakes are prevalent & relevant

<http://earthquake.usgs.gov/earthquakes/recenteqsww/>



Red-last hour Yellow-last week Blue-last day

“Name This City...1906”



EARTHQUAKE Prevalence

- Earthquakes are the most prevalent natural disaster
 - From 2000-2008 earthquakes accounted for 58.7% of fatalities of global natural disasters.
 - The Haitian earthquake had 20X death toll as all disasters in 2009 combined
- The predicted risk of earthquakes is high in parts of the world (Vos, CRED 2010)
 - There is a 62% chance that an earthquake of 6.7 magnitude will strike San Francisco by 2031

Morbidity & Mortality due to blunt trauma

Athens 1999 Earthquake (Padadopoulos et al, 2004)

Table 2 Mechanisms of injury and causes of 111 deaths

Total buried or trapped in collapsed buildings	102 (91.9)
Total with trauma of any severity and type	105 (94.6)
Total deaths caused by blunt and burn injuries	74 (66.7)
Directly related to earthquake	103 (92.8)
Buried or trapped and died from blunt trauma	69 (62.2)
Buried or trapped and died from asphyxia	31 (27.9)
Asphyxia with trauma \geq AIS3 (ISS 9–18)	14 (12.6)
Asphyxia with trauma $<$ AIS3 (maximum ISS \leq 6)	17 (15.3)
Struck by an object, died from blunt trauma	1 (0.9)
Buried or trapped and died with burns	2 (1.8)
Indirectly related to earthquake	8 (7.2)
Acute myocardial infarction (no injury)	6 (5.4)
Falls or jumps, died from blunt trauma	2 (1.8)

Values in parentheses are percentages. AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

Interesting

FACT:

Kidney failure has been identified by the Centers for Disease Control and Prevention as one of the most urgent public health concerns in Haiti following the 7.0-magnitude earthquake.

The injured extremities do not appear to be life-threatening!



Definition of Crush Syndrome

- Syndrome of traumatic rhabdomyolysis causing myoglobinuric renal failure, muscle re-perfusion
 - Involvement of muscle mass
 - Prolonged compression (usually 4-6hours)
 - Compromised local circulation
 - Release of toxins triggering hypovolemic shock & hyperkalemia

Recent Earthquakes & Incidence of CRUSH Syndrome

Sever MS et al. N Engl J Med 2006;354:1052

1063

Table 1. Statistics Related to Major Earthquakes in the Past 18 Years.*

Location and Year	Death	Crush Syndrome <i>overall number of crush victims</i>	Dialysis
Spitak, Armenia, 1988 ¹⁵⁻¹⁷	25,000	600	225-385
Northern Iran, 1990 ¹⁸	>40,000	?	156
Kobe, Japan, 1995 ^{19,20}	5,000	372	123
Marmara region, Turkey, 1999 ²¹	>17,000	639	477
Chi-Chi, Taiwan, 1999 ²²	2,405	52	32
Gujarat, India, 2001 ²³	20,023	35	33
Boumerdes, Algeria, 2003 ²⁴	2,266	20?	15?
Bam, Iran, 2003 ²⁵	26,000	124	96
Kashmir, Pakistan, 2005 ²⁶ †	>80,000	118	65
Total	>217,000	>1900	>1200

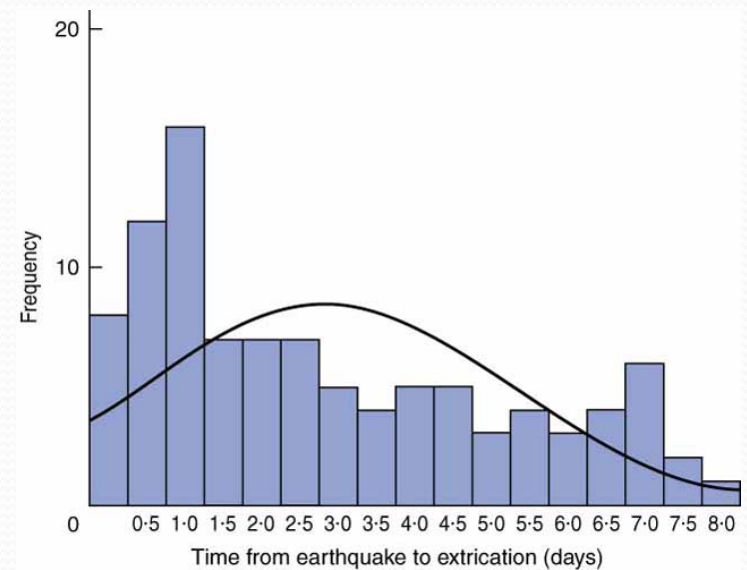
* Data are from Vanholder et al.¹³ and the U.S. government.¹⁴

† The latest data as of December 11, 2005, are given and are limited to the major reference centers of Islamabad and Abbottabad; data were provided by Drs. Asrar Hussain and Sameeh Khan, our Pakistani contact who handled the statistical follow-up.

CRUSH Injuries Result from Blunt

Trauma & Entrapment Padadopoulos et al, 2004

- No correlation with degree of crush injury & time under rubble (Iskit et al, 2001)
- The average extrication time from the 1999 earthquake in Athens was 2.1 days.



Interesting FACT

Myoglobin was first identified as cause of renal failure in 1943

- First described in 1941 by Bywaters and Stead in the Battle of Britain
 - 4 patients with crush injury all developed renal failure & died. Pigmented casts were discovered in the renal tubules.

- In 1943 Bywaters and Stead used a rabbit model to identify myoglobin as a cause of renal failure (Bywaters, JAMA 1944)

Description by Bywaters in the Battle of London in WWII

“Amongst air-raid casualties seen at this hospital have been four cases of crush injury...The patient had been **buried for several hours with pressure on the limb**. On admission he looked good except for **swelling** of the limb, some **local anesthesia** and whealing. A few hours later the **blood pressure falls**. This is restored to preshock levels by transfusions of serum, plasma, or occasionally blood. The **urinary output, initially small, diminishes** further. The urine contains albumin and many dark brown or granular casts. Slight generalized edema and incessant **vomiting** develop. The blood urea and potassium, raised at an early stage, become progressively higher and **death** occurs comparatively and suddenly, frequently within a week.”

Surprising FACT:

CRUSH Syndrome can develop in a limb with a normal blood supply



Causes of Rhabdomyolysis

- **1) Traumatic or compression**
 - **Multiple trauma**
 - **Crush injuries**
 - **Vascular or orthopedic surgery**
 - **Coma Immobilization**
- **2) Exertional damage in normal muscle**
 - **Extreme exertion**
 - **Environmental heat illness**
 - **Seizures**
 - **Hyperkinetic states**
 - **Malignant hyperthermia, neuroleptic malignant syndrome**
- **3) Non-exertional damage in normal muscle**
 - **Drug and toxins**

Mechanism of Cellular Injury

- 1) Sarcolemmal stretch due to compression
- 2) Influx of Na, H₂O, calcium flows down electro-chemical gradients
- 3) Cell swelling & lysis-release of toxins (myoglobin, K⁺, lactate)
- 4) Cationic pumps function at full capacity & cell depleted of energy
- 5) Mitochondria fail to function

Interesting FACT

CRUSH Injuries affect more than limbs!

- Renal: Acute renal failure
- Multi-organ: Sepsis
- Pulmonary: ARDS
- Hematology: DIC
- Cardiac/Electrolyte: Arrhythmias, ie. torsades from elevated K

CRUSH Syndrome & Renal Failure in 3 Recent Earthquakes

- ***Hanshin-Awaji, Japan***
 - 6% hospitalized patients (N=372) had crush injury
 - 13% of those with crush injury died
 - Causes of death: hypovolemia, hyperK (most within 1st 2days before initiation of dialysis).
- ***Marmara, Turkey***
 - 12% of hospitalized patients with renal failure related to crush injury
 - 9% dialysis dependent
- ***Kobe earthquake***
 - Crush injury in 13% of hospitalized patients
 - Acute renal failure in approximately 6% of hospitalized patients

Mechanism of Renal Injury

- **#1: Toxic effects of myoglobin: lipid peroxidation. Oxidative damage to cell membranes**
- #2: Decreased renal perfusion due to decreased intravascular volume. Renal vasoconstriction due to platelet activating factor & endothelin-1
- #3: Tubular obstruction
 - Myoglobin is LARGE & freely filtered, but not absorbed.
 - Myoglobin reacts with Tamm-Horsfall protein forming casts

Fatal arrhythmias

- Damaged muscle releases K^+ into the circulation
- Potassium is critical in cell re-polarization
- In hyperkalemia ventricular depolarization is prolonged, therefore QRS widens
- If persistent, a fatal ventricular arrhythmia results: torsades de points

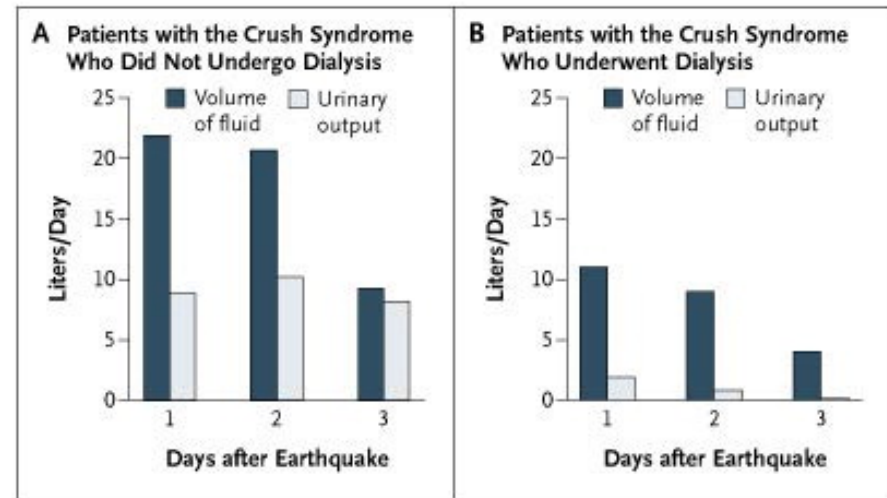


Work-up for suspected rhabdomyolysis

- Check STAT electrolytes to rule-out hyperkalemia
- Estimate hydration status with BUN and clinical measures
- Examine extremities carefully for signs of compartment syndrome
- Check renal function & CK

Therapy: Importance of Early Hydration in Rhabdomyolysis

- Vigorous hydration, of at least 20cc/kg/hour in children and >20L/day in adults
 - Saline vs. alkalized fluids.
- If urine output <2cc/kg/hr , consider giving mannitol (1g/kg) to increase the elimination of myoglobin by the kidney.
- Data from Bingol, Turkey



What therapies work?

- Early & Aggressive Hydration
 - May not prevent loss of limbs, but may save kidneys & multi-organ failure
- Early fasciotomy to preserve limbs due to elevated compartment pressures
- Antimicrobial therapy to prevent/treat sepsis

Poor Outcomes in Crush Syndrome & Renal Failure

- Thoracic and abdominal trauma correlates highly with mortality
- Fasciotomy is associated with sepsis and need for dialysis ($P < 0.001$)
- Amputations are independently associated with mortality ($P < 0.0001$)
- DIC and ARDS are independent predictors of mortality ($P < 0.0001$)
- Data from Marmara earthquake in 1999 (N=639)
Sever et al, 2002

Earthquake Case

- **Scene:** Front-lines ICU tent in Pakistan after a recent 8.0 earthquake, 30 hours post earthquake.
- **Situation:** A moaning 6yo child arrives on a stretcher wearing an O₂mask. She was found trapped under a cement staircase with her chest partially exposed. You immediately notice shallow breathing.

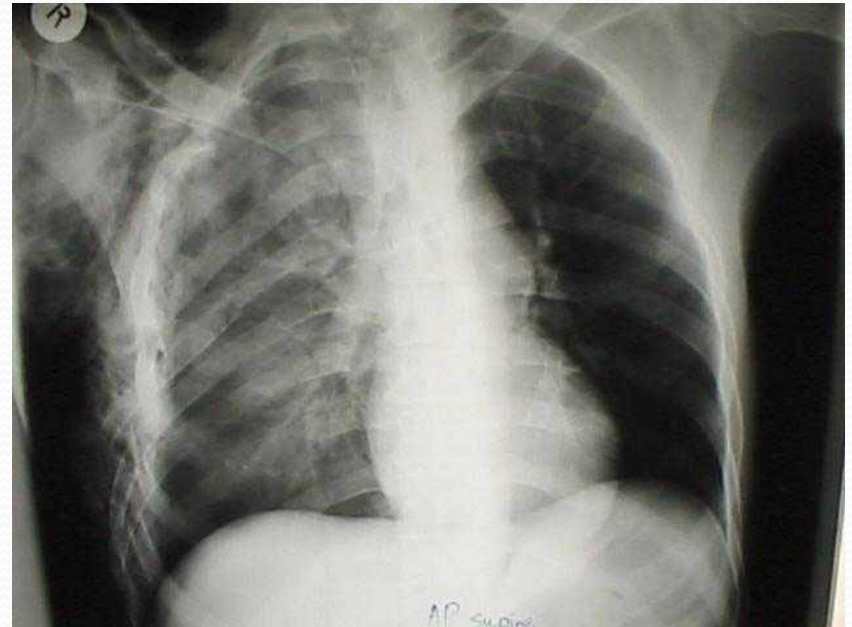


Earthquake Case: Exam

- **Exam:**
- **Vitals:** Pulse oximetry reveals an O₂ saturation of 90%, her RR is 45 breaths/min, and heart rate is 120/min.
 - Decreased air movement in right chest
 - There is swelling of her right leg to the mid-thigh with obvious tissue maceration. She is unable to move her right thigh, but can wiggle her toes. Her pulses still remain strong centrally and peripherally in both extremities. Her abdomen is soft and non-distended and she cooperates with your exam.
 - She appears very fatigued and at times does not respond to questions. A foley catheter is placed and there is dark urinary output.

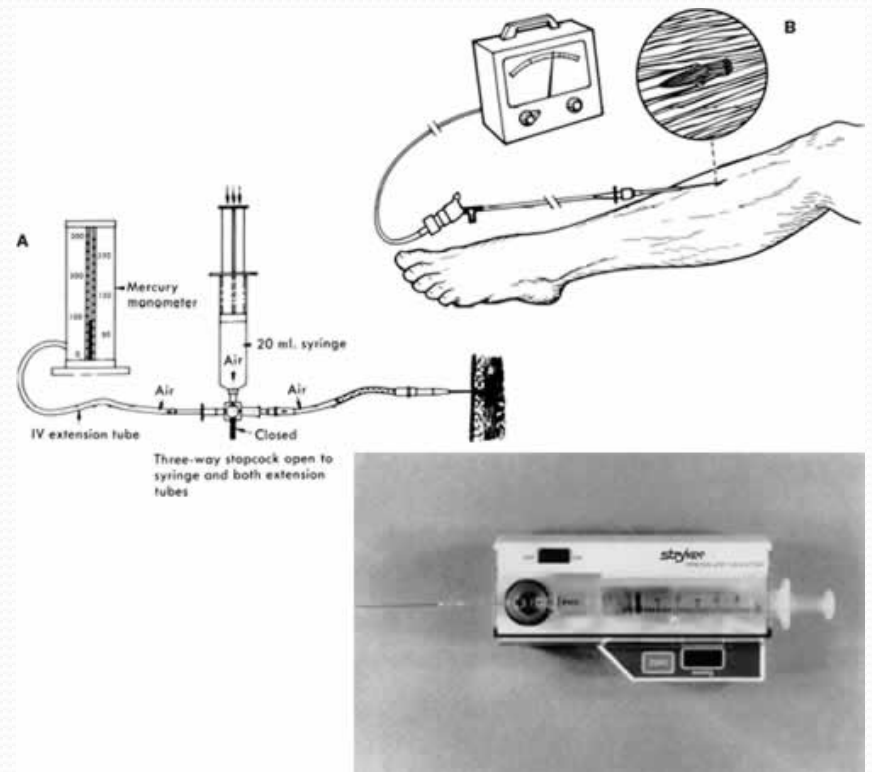
Initial Patient Evaluation

- **Airway/Breathing:**
 - CXR reveals thoracic rib fractures X 4 in the right chest and a diffuse hazy appearance of the right lung.
- **Circulation/Rhythm:**
 - Pulses in extremity strong
 - EKG reveals normal sinus rhythm, no signs of ST segment elevations/depressions



Initial Patient Evaluation

- Secondary Survey, ie: crushed limb:
 - Right limb is swollen, pale
 - Measure compartment pressures with manometer.
 - Right thigh pressure= 15 (pressures >30mm Hg usually require surgical decompression)



Conclusions & Priorities of Care

- Airway/Breathing: Flail chest & pulmonary contusion
- Circulation: Compensated shock
- Disability/Secondary Survey: Crush injury of the right leg evolving into crush syndrome-acidosis and oliguria (ARF). Waxing & waning mental status (?uremia).
 - Significant limb swelling and dyskinesia, mild signs of compartment syndrome.
 - No pain, pallor, paralysis, paresthesias, and pulselessness or interponneurosis pressure >30. **No need for emergent fasciotomy.**
- Transfer patient while stable anticipating future dialysis and ventilatory needs

Conclusions: CRUSH Syndrome

- CRUSH Syndrome is very common in earthquake situations & can result in compartment syndrome with loss of limb as well as multi-organ failure.
- Hyperkalemia and hypovolemic shock are the most common initial causes of death in crush injury.
- Renal failure is often prevented with aggressive and early fluid resuscitation.

Man uncovered alive after being buried for 14 days in Haiti



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