Management of Crush Related Injuries

After a Disaster

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RENNAL DISASTER / CRUSH SYNDROME

- Introduction
- Etiology / pathogenesis
- Clinical / lab. findings
- Prophylactic / therapeutic interventions

LOGISTIC ISSUES

- Severity assessment
- Providing health care
- Medical support
- Other logistic issues

CONCLUSIONS
GLOBAL SEISMIC HAZARD MAP

EARTHQUAKES: A WORLDWIDE PROBLEM
THE MARMARA EARTHQUAKE:
One of the most catastrophic Disasters of the World in the 20th Century

- 17 August, 1999
- 7.4 (Richter scale)
- 45 sec
- Deaths: 17,480
- Injured: 43,953
The Marmara Earthquake

- Pts. with renal prob.: 639
- Pts. requiring Dx.: 477

The Hanshin-Awaji (Kobe) Earthquake

- Pts. with ARF: 202
- Pts. requiring Dx.: 123

The largest “renal disaster” documented so far!

Sever et al. Kidney Int 2001
Oda et al. J Trauma 1997
Dialysis for acute renal failure due to crush injuries after the Armenian earthquake


N T Richards, J Tattersall, M McCann, A Samson, T Mathias, A Johnson

On 7 December 1988 an earthquake measuring all patients develop acute renal failure at the same time,

“RENAL DISASTER”

*Kidney Int* 1993; 44: 479-83

**INVITED CONTRIBUTION**

International dialysis aid in earthquakes and other disasters


University of Alberta Hospitals, 5B4.02 W.C. Mackenzie Health Sciences Centre, Edmonton, Alberta, Canada; Guy's Hospital, London,
80% die instantly
10% minor injuries
10% major injuries

Crush syndrome
2nd most frequent cause of deaths (following direct effect of trauma)

“RENAL DISASTER”

Ron et al. Arch Intern Med 1984
Ukai. Ren Fail 1997
**Crush**: injury due to pressure between opposing elements

**Crush syndrome**: systemic manifestations of crush injury-induced rhabdomyolysis

**SURGICAL**
- Local findings of trauma
- Compartment syndrome

**MEDICAL**
- Hypovolemic shock
- Hyperkalemia
- Infections
- Acute renal failure
Rhabdomyolysis: Disintegration of striated muscles that results in release of muscular cell contents into the extracellular fluid

Muscles: largest organ system in the body (40% of body weight)
The risk to be traumatized is very high

- lactic acid
- thromboplastin
- creatin kinase
- nucleic acids
- phosphate
- creatine

- Myoglobin
- Potassium

CRUSH SYNDROME
TERMINOLOGY - III

- **Compartment**: space restricted by the rigid fasciae surrounding the muscles

**Compartment syndrome**

- increased pressure in the compartments due to traumatic tissue swelling

Disrupts perfusion / hinders muscle function
TERMINOLOGY - IV

Fasciotomy

- surgical incision through the fasciae to reduce intracompartmental pressure

Decompressive intervention
CRUSH SYNDROME:
2nd most frequent cause of deaths

Underlying pathology in crush syndrome

RHABDOMYOLYSIS
RENA成功 DISASTER / CRUSH SYNDROME

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CONCLUSIONS
ETIOLOGY of RHABDOMYOLYSIS

<table>
<thead>
<tr>
<th>Non-traumatic</th>
<th>Traumatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Metabolic myopathies</td>
<td>• Traffic or working accidents</td>
</tr>
<tr>
<td>• Drugs and toxins</td>
<td>• Prolonged immobilization</td>
</tr>
<tr>
<td>• Infections</td>
<td>• Vessel clamping</td>
</tr>
<tr>
<td>• Electrolyte abnormalities</td>
<td>• Strainful exercise of muscles</td>
</tr>
<tr>
<td>• Endocrine disorders</td>
<td>• Electrical current</td>
</tr>
<tr>
<td>• Polymyositis, dermatomyositis</td>
<td>• Hyperthermia</td>
</tr>
<tr>
<td></td>
<td>• Disasters</td>
</tr>
</tbody>
</table>

Vanholder et al. JASN 2000
PATHOGENESIS of CRUSH SYNDROME

I. Traumatic rhabdomyolysis

II. Rhabdomyolysis-induced ARF

Better and Stein. NEJM 1990
Vanholder et al. JASN 2000
PATHOGENESIS of TRAUMATIC Rhabdomyolysis

Ca++

Na+

Cl-

H2O

Ca++

Proteolytic enzymes

PO42+

Creatin

Myoglobin

K+

H+

Rhabdomyolysis

Uric acid

COMPARTMENT SYNDROME
PATHOGENESIS of Rhabdomyolysis-Induced ARF

A. Intravascular volume depletion
   - Compartment syndrome
   - Vasoconstrictor substances

B. Direct toxicity of myoglobin

C. Intratubular obstruction (myoglobin, uric acid)

D. Other factors
   - Free iron
   - Hyperphosphatemia
   - Hyperuricemia
   - Disseminated intravascular coagulation
   - Free radicals
   - Infection
   - Drug induced nephrotoxicity

Better and Stein. NEJM 1990
Vanholder et al. JASN 2000
# RENAL DISASTER / CRUSH SYNDROME

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## LOGISTIC ISSUES

- Severity assessment
- Providing health care
- Medical support
- Other logistic issues

## CONCLUSIONS
CLINICAL FINDINGS

Local findings in the traumatized muscles (6 “P”s)

1. Pain
2. Pressure
3. Paresthesia
4. Paresis or paralysis
5. Pallor
6. Pulselessness

Systemic manifestations of rhabdomyolysis (C.S.)

• Hypovolemic shock
• ARF
• Hyperkalemia
• Heart failure
• ...............
LABORATORY FINDINGS

**Urinary findings**
- Myoglobinuria
- Other findings

**Biochemistry**
- Muscle enzymes
- Creatinine / BUN
- Acidosis
- Hyperphosphatemia
- Hyperuricemia
- Hypocalcemia
- Hypoalbuminemia
- Abnormal blood count
- Hyperkalemia
SERUM POTASSIUM ON ADMISSION
(The Marmara Earthquake Experience)

5.3 ± 1.3 (2.4 – 13.3) mmol/L

Many patients died at the disaster field or within the first hours of admission to hospitals due to fatal hyperkalemia!

• Rescued victims who were seemingly well under the rubble, deteriorated or even died as soon as after extrication!

- Severe metabolic acidosis
- Fatal hyperkalemia

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CONCLUSIONS
EARLY FLUID ADMINISTRATION IS OF VITAL IMPORTANCE!

(1 L/hr saline)

- After the rescue ➔ alkaline solution
- Adequate urine response ➔ + mannitol ➔ 8 - 12 L/day
- Less aggressively (4 - 6 L/day) in disasters

CVP measurements

Better and Stein. NEJM 1990
Vanholder et al. Kidney Int 2000
THERAPEUTIC INTERVENTIONS

MEDICAL

• Blood and blood product transfusions
• Renal replacement therapy
• Treatment of infections and other complications

SURGICAL

• Management of traumatic wounds, amputations
• Fasciotomy
BLOOD and BLOOD PRODUCT TRANSFUSIONS
(The Marmara earthquake experience)

Blood: 2981 u.
FFP: 2837 u.
H. alb.: 2594 u.

\[ \text{Total Transfusions (U)} = 8500 \]

- Medical concerns
- Logistic concerns

Sever et al. Nephron 2002
Dialysis indications:

- Clinical symptoms of uremia
  (hypertension, volume overload, nausea...)
- Biochemical abnormalities
  (severe uremia, hyperkalemia, acidemia..)

Prophylactic dialysis
- High risk for hyperkalemia

Sever et al. Kidney Int 2002
RENAL REPLACEMENT THERAPY -II
(The Marmara Earthquake experience)

RRT support in 477 (74.6%) patients

IHD: 462, SCT: 34, PD: 8

Sever et al. Kidney Int 2002

HD sessions: 11.1±8.0
Days on HD: 13.4 ±9.0

5137 sessions of IHD

Sever et al. Kidney Int 2002
FASCIOTOMIES in the Marmara E.

397 fasciotomies in 323 patients

Sepsis:
- Fasc. (+): 25%
- Fasc. (-): 13%

Mortality:
- Sepsis (+): 27%
- Sepsis (-): 12%

Fasciotomies ⇒ objective criteria

Sever et al. NDT 2002
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CONCLUSIONS
LOGISTICS

- Procurement
- Maintenance
- Distribution
- Replacement

Personnel / material

Vital in disasters due to chaotic conditions
Support is offered, if needed

Anticipation of the needs for support (i.e. medications, blood products)

Inform RDRTF Branch Chairman (international support)
Inform local authorities (national support)

Sever, Vanholder, Lameire. NEJM 2006
LOCAL LOGISTIC INTERVENTIONS

I. Severity assessment
II. Providing health care
   • Rescue activities
   • Evacuation of the victims
   • Logistic planning in hospitals
III. Medical support
IV. Other logistic issues
   • Global logistic needs
   • Managing chr. patients
   • Medical records
### SEVERITY ASSESSMENT - I

<table>
<thead>
<tr>
<th>Event</th>
<th>Calculation</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following major earthquakes:</td>
<td>Deaths / Injured: $\approx 1 / 3$</td>
<td></td>
</tr>
<tr>
<td>The Marmara Earthquake:</td>
<td>$\approx 1 / 2.5$ (17,480 / 43,953)</td>
<td></td>
</tr>
<tr>
<td>Crush syndrome in the injured:</td>
<td>2 - 5%</td>
<td></td>
</tr>
<tr>
<td>The Marmara Earthquake:</td>
<td>$\approx 1.5%$ (639 / 43,953)</td>
<td></td>
</tr>
</tbody>
</table>

2 - 3% of all casualties ~ crush syndrome

Alexander, Disasters, 1996  
Sever et al, Kidney Int, 2001  
Zhi-Yong, J Trauma, 1987
SEVERITY ASSESSMENT - II

Many factors effective!

- Intensity of the disaster
- Population density of the region
- Structural characteristics of buildings
- Timing (moment) of disaster
- Efficacy of rescue activities

Noji et al., 1990; Nadjafi et al., 1997

Gujarat Earthquake:
Death: 19,727, Cr.: 35

Bam Earthquake:
Death: 26,000; Cr.: 124

September 11 terrorism
Death: >3,000; Cr.: 1

Viroja et al, WCN Abstracts, 2001
Argani et al, JASN, 2004
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CONCLUSIONS

- Rescue Activities
- Evacuation of the victims
- Logistic planning in hospitals
People living in disaster prone regions should consider that they are needed as "rescuers" in the case of a disaster.

Noji et al. 1993

De Bruycker et al., 1985
The Marmara Earthquake:
11.7±14.3 (0.5-135) hrs.
Sever et al. KI 2002

Kobe Earthquake:
9 hrs.
(Oda et al, J Trauma 1997)

Rescue activities within the first 2 days are of vital importance.
EVACUATION of the VICTIMS

- Aftershocks may further damage hospitals
- Keeping positions open for untransportable cases
- Locally treated patients have a higher risk of mortality

Kuwagata et al, 1997

Administer potassium binders before transportation!
In disasters most admissions occur within 3 days

Noji, 1990

Mildly injured victims:
- Arrive shortly after disaster
- Occupy positions of more seriously wounded cases, who often arrive later.
- Can be followed as outpatients

Sever, Vanholder, Lameire. NEJM 2006
LOGISTIC PLANNING in HOSPITALS - II
(Status of health care personnel)

- Personal harm to themselves or family members
- Work overload
- Panic and depression

Ukai, 1997; Waeckerle, 1991

INEFFECTIVE WORK

- Experienced personnel $\Rightarrow$ first days
- Avoid “burn-out” syndrome
- Clear guidelines may minimize risk of malpractice

MACROPLANNING

- Field
- Emergency Units
- Clinical Follow-up
- Coordination
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CONCLUSIONS
SUPPORT of MEDICAL MATERIAL and PERSONNEL

International relief ≠ functional help

- Guatemalan e. → 90% drugs useless (unsorted)  
  Seaman, Injury, 1990
- Armenian e. → 70% useless (expired or damaged)  
  Auiter, Lancet, 1990

International personnel support → useful or harmful

Local / Global integrated responses are mandatory!
ANTICIPATING THE NEEDS FOR MEDICAL ITEMS

**Crystalloids** ⇒ 5L / pt./day ... (3000x5x7) = 105,000 L

**Kayexalate** ⇒ 15 g / pt/day.. (3000x15x7) = 315 kg

**HD sess.** ⇒ 11 / pt ...(3000x 0,75X11) = 24,750 sets

**Blood:** 4,6 x 3000=13,800; **FFP:** 4,4 x 3000=13,200; **Hum.Alb:** 4.0 x 3000=12,000

**OVERALL:** 39,000 U blood and blood products
CONCLUSIONS

• Disasters and subsequent "renal disasters" will continue to be major causes of death in the future.

• Number of deaths due to crush s. (renal disaster victims) can be decreased by appropriate management.

• Medical practice during disasters differ considerably as compared to routine medical applications.

• National / international disaster preparedness and logistic planning can be helpful to decrease post-disaster chaos and provide effective health care.