**Evaluation and Management of Burns**

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**Epidemiology of Burns**

- 1-1.5% of population sees MD for burns/year
- 1.25-2.5 million burns each year
- 500,000 ED visits, 50,000 admits, 5,000 deaths
- Most burns cover less than 5-10% of body surface area

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**Mortality from Burns**

- Most deaths occur at home
- Causes of death
  - Smoke inhalation, sepsis, pneumonia, shock
- More common in elderly (age+BSA=%mortality), most with >70% die
- Risk factors for death
  - > 40% BSA, > 60 years, inhalation injury

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**Pathophysiology of Burns**

- Dynamic injuries
- Cellular damage at >45°C
  - Dependent on temperature and duration  
    - Singer et al. Acad Emerg Med 2000;7:1
- Three zones of injury
  - Central necrosis
  - Zone of stasis (at risk of necrosis)
  - Zone of hyperemia
  - Jackson Br J Surg 1953;40:588

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**Burn Pathophysiology**

- Thermal injury triggers intense inflammatory response
- Initial release of histamine, bradykinin
- Increased capillary permeability with third spacing
- Progressive vascular occlusion by PMN, RBCs
- Release of prostanoids, free radicals, proteases
- Intense inflammatory response target of new therapies
- May result in MOF, CV collapse, disruption of GI permeability

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**Potential Burn Therapies**

- Anti-inflammatory agents
- Heparin
- Corticosteroid
- Anti oxidants
- Variable success, non-significant improvements
**Burn Classification**

- Extent and depth of injury dictates therapy and prognosis
- Age, comorbid conditions, associated trauma contribute to severity
- Problematic anatomical areas
  - Face, perineum, hands and feet, circumferential burns

**Classification of Burns Severity**

<table>
<thead>
<tr>
<th>Burn Severity</th>
<th>Age</th>
<th>Children</th>
<th>0-19% TBSA</th>
<th>Full thickness &lt;19% TBSA</th>
<th>Full thickness &gt;19% TBSA</th>
<th>Full thickness &gt;20% TBSA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor</td>
<td>Adult</td>
<td>Full thickness &lt;19% TBSA</td>
<td>Full thickness &gt;19% TBSA</td>
<td>Full thickness &gt;20% TBSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe</td>
<td>Elderly</td>
<td>Full thickness &lt;19% TBSA</td>
<td>Full thickness &gt;19% TBSA</td>
<td>Full thickness &gt;20% TBSA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Critical areas include face, hands, feet, perineum
- Comorbid conditions can include diabetes mellitus

**Burn Depth**

- First-degree: Epidermis only
  - Hyperemia, blanches with pressure
  - (Significant) pain
  - Heals within 1-2 weeks

- Second-degree (superficial)
  - Epidermis and superficial dermis, skin appendages intact
  - White appearance
  - Edema may be present
  - 1-2 weeks

- Second-degree (deep)
  - Epidermis and most dermis, some skin appendages destroyed
  - White appearance
  - Edema may be present
  - 2-3 weeks

- Third-degree
  - Epidermis and all of dermis, destruction of all skin appendages
  - White, charred
  - Does not blanch
  - Aesthetic, not painful
  - Does not heal
  - Requires treatment

**Methods to Determine Burn Depth**

- Clinical evaluation
  - Accuracy of 50% only
    - Hlava et al. *Acta Chir Plast* 1983;25
- Investigational methods
  - Vital dyes, fluorescein fluorescence, US, thermography, light reflectance, laser doppler, MRI
- Methods detect cell death, blood flow, edema
- Inconsistent reliability
- Histological evaluation most accurate yet invasive
**Initial Burn Management**
- Follow ABCs
- Identify and treat associated injuries (explosions)
- Remove patient from source, protect rescuer, drop roll-over
- Initial cooling with cold (not ice) water, cover with sterile dressing, leave blisters intact
- Brush off any metal or powder, copious irrigation for chemical burns

**Airway and Breathing: Prehospital Phase**
- Secure airway early
- Impending airway obstruction (hoarseness, stridor, facial edema) should be managed with orotracheal intubation or surgical airway if TI impossible
- Give 100% O₂ for suspected smoke inhalation
- Consider direct fiberoptic laryngoscopy in ED

**Circulation – Prehospital Phase**
- IV fluids indicated for all but minor burns
- Balanced crystalloid solution
- Large peripheral IV catheter
- May be initiated en route to avoid delays

**Further ED Management**
- History of events
  - Occult trauma, closed space, toxic fumes, evaluate for inconsistencies or patterns suggesting child abuse (immersion injuries)
- PMH
  - AMPLAR
  - Tetanus immunization status (contaminated wound)
  - Allergy to sulfa precludes use of SSD
- Physical exam
  - Assess for inhalation injury (classic signs often absent)
  - Singed nasal hair, carbonaceous sputum, cough, hoarseness, dyspnea, AMS

**Determining Extent of Injury**
- Burn extent determines therapy and prognosis
- Burn size estimate often inaccurate
- Extent of injury described using percentage of total body surface area that is burned (TBSA)
- For patients > 9 “rule of nines” may be used
- For small burns, the patient’s palm covers 0.5%
- With young children proportions differ

**Estimating BSA in Adults**

Figure 1. Estimating the percent total body surface area of burns in adults.
Evaluation of Burns – cont.
- Look for circumferential burns to chest, neck and limbs that may compromise ventilation or circulation
- Loss of distal pulses late
  - Assess for warmth, sensation, motor, rigidity
  - Doppler exam helpful
- Identify potential abuse
  - Well circumscribed, feet, ankles, buttocks
  - Stigma of cigarette butts or other hot objects
  - Inconsistent history

Laboratory Evaluation
- With major burns
  - CBC, lytes, coags
  - Bedside glucose if AMS
  - ABG and CO levels if AMS, HA, CP, closed space, respiratory distress
  - Pulse Ox falsely elevated with CO poisoning
  - Acidotic patient with normal CO and AMS suggests CN
  - UA and CPK to exclude rhabdomyolysis and myoglobinuria in deep burns, electrical burns

Radiographic Studies
- CXR
  - Severe burns
  - Suspected inhalation injury
    - Nodules, consolidation, interstitial edema, atelectasis
  - Initial CXR by be normal in 1/2 of patients with inhalation injury (lag time)
  - C-spine /Head CT with suspected associated injuries

Further ED Management
- Focus on ABCs
- Early involvement of burn specialist
- Goals
  - Identify and treat airway compromise, inhalation injury, associated trauma, initiate fluid resuscitation, pain management
- IVF, NG, Urethral catheter with burns > 20% in adults (>10% in children)
- Tetanus prophylaxis
  - With prior immunization, Td every 5 years
  - Without prior immunization Td and TIG 250 U
- Antibiotics not routinely given

Need for Escharotomies
- Deep circumferential burns over neck, chest limbs
- Compromised airway, breathing, or circulation
- May be life or limb threatening
- Incision of eschar to sub Q fat
- Avoid major vessels and nerves
- Anesthetics usually not required

Pain Management
- Most burns very painful and under treated
- IV narcotics recommended
- MSO₂ 2-4 mg q 5-10 minutes and titrated
- Intubated patients may also require sedation
- Cold water compresses for smaller burns

Smoke Inhalation Injury
- Responsible for most deaths
- Evolution may require several days
- Exposure of airways and lungs to toxic chemicals
- Tracheobronchitis, epithelial fibrin casts
- Airway obstruction, PMN activation with release of oxygen radicals, proteases
- Pulmonary edema within 2-3 days

Smoke Inhalation
- Hypoxemia, elevated CO or LA
- CXR may be normal
- CT of chest more sensitive
- Physical findings may be suggestive (carbonaceous sputum, singed vibrissae, facial edema, stridor)
- Bronchoscopy allows direct visualization
- When combined with xenon scan 93% accuracy

Treatment of Smoke Inhalation
- Fluid resuscitation initially felt to be bad
- Recent studies suggest that patients with burns and inhalation injury require 2ml/%TBSA/kg more than w/o inhalation
  - Herndon et al. Surgery 1987;102:341
- 100% O₂
- Consider intubation
**Indications for Tracheal Intubation**
- Significant or rapidly progressive airway edema
- Tachypnea with use of accessory muscles
- Arterial hypoxemia (<70) despite O₂
- Ratio of partial pressure of arterial O₂ to fraction of inspired O₂ less than 200
- RSI for most patients
- Depolarizing agents may raise K after 3-10 days
- Consider awake intubation with massive airway edema and spontaneous respirations

**Treatment of Inhalation Injury**
- Standard volume-controlled respirators may lead to barotrauma
- High frequency percussive jet ventilation reduces airway pressures and improves survival in comparison with controls
- Free radical scavengers, heparin, ibuprofen
  Evidence of improvement in animal studies only
- Corticosteroids and antibiotics not effective

**Treatment of Inhalation Injury**
- CO and CN poisoning may be present
- O₂ accelerates CO elimination
- Traditional indications for hyperbarics:
  - CO >25% (or >15% in pregnancy, infant)
  - Myocardial ischemia
  - Neuropsychiatric abnormalities or prior coma
- Recent Australian study utility of hyperbarics even in severe poisonings
- Suspect CN in comatose, severely acidic patients with normal CO
- Treat with amyl nitrate, sodium nitrite, sodium thiosulfate

**Fluid Resuscitation**
- Hypovolemia was major cause of death
- Massive transudation of fluids from vessels due to increased permeability
- Edema intensifies over 8-48 hours
- Goal: preservation of organ perfusion and urine output
- Rapid resuscitation in children (1/2 over 4 hours) may be preferred

**Hyperbaric oxygen for acute carbon monoxide poisoning**
- Three hyperbaric-oxygen treatments within a 24-hour period appeared to reduce the risk of cognitive sequelae 6 weeks and 12 months after acute carbon monoxide poisoning
- 19 of 76 (25%) vs. 35 of 76 (46%, P=0.007)
- After adjustment for cerebellar dysfunction and for stratification variables odds ratio, 0.45 (95% CI, 0.22 to 0.92); P=0.03).

  Weaver et al. NEJM 2002; 347:1057

**Fluid Resuscitation**
- Many different formulas
- Crystalloids preferred over colloids during first 12-24 hours
- Use of hypertonic saline advocated by some
  - Conflicting data regarding mortality and ARF
- Parkland formula most commonly used
  - Based on small retrospective study and animal study
  Baxter Ann NY Acad Sci 1983;575
- Rough guidelines only
- Adjust to clinical response
  - U/O > 0.5-1.0 ml/kg/hr
Table 6. Fluid Resuscitation Formulas.

<table>
<thead>
<tr>
<th>Formulas</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystalloid Formulas</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Standard</strong></td>
</tr>
<tr>
<td></td>
<td>- Lactated Ringer’s 4 mL/kg TBSA/burn</td>
</tr>
<tr>
<td></td>
<td>- One-half of calculated needs in first eight hours, the rest over 16 hours</td>
</tr>
<tr>
<td></td>
<td><strong>Modified</strong></td>
</tr>
<tr>
<td></td>
<td>- Lactated Ringer’s 2 mL/kg TBSA/burn</td>
</tr>
<tr>
<td></td>
<td>- Hyperoncotic Saline</td>
</tr>
<tr>
<td></td>
<td>- Saline solution containing sodium 250 meq/L, 0.6 mL/kg TBSA/burn plus twothirds isotonic salt solution only up to 3.5 mL/kg/</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Colloid Formulas</td>
<td><strong>(under recent question see reference 83)</strong></td>
</tr>
<tr>
<td></td>
<td>- Lactated Ringer’s 1.5 mL/kg TBSA/burn + 0.5 mL/kg Colloid = 2,000 mL D5W</td>
</tr>
<tr>
<td></td>
<td>- Normal saline 1.0 mL/kg TBSA/burn + 1.0 mL/kg TBSA/burn + 2,000 mL D5W</td>
</tr>
<tr>
<td></td>
<td>- Water</td>
</tr>
<tr>
<td></td>
<td>- Lactated Ringer’s 2,000 mL/24 hr = Fresh frozen plasma 75 mL/kg/24 hr</td>
</tr>
</tbody>
</table>

**Increased Fluid Needs**

- Children
- Large burns
- Smoke inhalation injury
- Delayed resuscitation
- Formulas based on BSA more accurate in kids
  - 5L/m² + 2L/m² (use crystalloids containing glucose)

**Fluid Creep**

- First described by Pruitt
- Excessive fluid resuscitation in the belief that more is better
- Consequences may be life threatening
- Modified Brooke formula, (2 ml/kg/%burn) with lower initial volume preferred

**Fluid creep**

- Average volumes administered often exceed 5-7 ml/kg/%burn
  - Cancio et al J Trauma 2004;56:404
  - Engrav et al. J Burn Care Rehab 200;21:91
- Retrospective review of 483 patients
  - 43% adequate resuscitation
  - 40% over-resuscitation

**Causes of fluid creep**

- Overestimation of burn size common
- Goal directed therapy with restoration of supra-physiological parameters with use of invasive monitors
- Hesitancy to reduce fluid rates with adequate UO
- Opioid creep leading to vasodilatation
- Higher likelihood with more severe burns (>80% TBSA)

**Over-resuscitation**
**Abdominal compartment syndrome**
- Decreased pulmonary compliance
- Cardiac dysfunction
- Malperfusion to bowel, liver, and kidneys
- Risk increased by high infusion rates
  - > 0.25 L/kg
- Risk lowered by use of colloids after 12-24 hr
  - Albumin leakage may be over within 12 hrs

**USA ISR Formula**
- Burn flow sheet instituted in 2005
- Lower initial volumes (2 ml/kg/%TBSA) used successfully
- Lower rate of ACS
- "Rule of Ten"
  - %TBSA multiplied by 10 to derive initial hourly fluid rate
  - For every 10 kg above 80 kg, add 100 ml to this rate
  - Fluid rate over-estimated in <40kg; under estimated for >140 kg
  - Hourly adjustments based UO and clinical observation

**ABA Recommendations**
- Insufficient data to support standard treatment
- Guidelines
  - Burns > 20% TBSA require fluid resuscitation (C)
  - Common formulas 2-4 ml/kg/%TBSA/24 hrs (C)
  - Titrate to UO of 0.5-1.0 ml/kg (1-1.5 in kids) (C)
  - Add maintenance fluids in kids
  - Increased volume
    - Full thickness, inhalation, delayed resuscitation

**Options**
- Addition of colloids, especially after 12-24 hrs decreases volume requirements (A)
- Oral resuscitation in alert, moderate sized burns (C)
- Hypertonic saline only by experienced, with close monitoring of Na+ (B)
- High dose vitamin C worthy of further study to decrease volume (C)
- Plasma exchange as salvage procedure (C)

**Local Burn Wound Care**
- Most burns small, minor, may be treated in ED and released
- Goals: reduce infection, optimize healing, prevent scarring
- Clean burns with mild soap and water
  - May require narcotics
- Careful debridement of ruptured blisters and devitalized tissue
- Do not rupture intact blisters
  - Consider aspirating tense blisters

**Burn blister care**
- Intact blister barrier to microbial invasion
- Intact blister creates moist environment
  - more rapid reepithelialization

  Gimbel et al. Arch Surg 1957;74:800*

  - more rapid angiogenesis
- Blisters rarely remain intact
  - rupture of blisters under contaminated conditions may increase infection rates
**Effects of blister fluid in vitro**

**Positive**
- Mitogenic to fibroblasts and rich in FGF and PDGF
- Rich in calmodulin which stimulates keratinocytes
- Contains IL-1, enhancing epidermal healing

**Negative**
- Vasodepressant prostaglandins leads to progressive injury
- Impairs neutrophil and lymphocyte function
- Inhibits keratinocyte proliferation and differentiation
- Impairs opsonic activity for Pseudomonas
- Inhibits fibrinolysis

**Prior Human Studies**
- Medical student volunteers
- Second degree contact burns
  - intact blisters
  - aspirated blisters
  - unroofed blisters
- Superficial burns epithelialize 40% more rapidly when blisters left intact


**Case Report**
- 14 year old girl with bilateral identical superficial blistering leg burns
- 36 hours after burning blisters removed from one leg
- Non-debrided burns
  - less painful
  - new epidermis thicker
  - better cosmetic results at 1 year

Forage Lancet 1962:690

**Effects of débridement of necrotic epidermis in pigs on infection rates**

**Reepithelialized wounds**

**Scar tissue**
**Dressings**
- Most wounds require a dressing
- Functions of dressing
  - Protects wound from further damage
  - Reduces evaporative fluid losses
  - Provides patient comfort
- Dressings continued till reepithelialization
- Use of skin moisturizers recommended
- Avoid exposure to sun for 12 months

**First Degree Burns**
- Dressings and topical agents not required
- Use of topical or systemic anti-inflammatory agents may reduce discomfort
  - Ibuprofen, aloe vera

**Second Degree Burns**
- Many therapies available
- Use of topical antimicrobial agents
  - Routine use decreases mortality
  - SSD most commonly used agent
  - Most agents require multiple applications
  - Bacitracin for head and neck, sulfamylon over cartridge (nose, ears)
  - Large exuding wounds

**Table 7. Topical Antimicrobial Agents.**

<table>
<thead>
<tr>
<th>Agent</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver sulfadiazine</td>
<td>- Good excoriation penetration</td>
<td>- Transient hypokalemia</td>
</tr>
<tr>
<td></td>
<td>- Combination application</td>
<td>- Ablery to use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Risk of hematoma (avoid in pregnant women and newborns)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Retarded healing in vivo</td>
</tr>
<tr>
<td>Silver nitrate</td>
<td>- Hypotonic solution may cause leaching of electrolytes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Ablery to use</td>
<td>- Corrosive to skin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Poor excoriation penetration (not for established infections)</td>
</tr>
<tr>
<td>Mafenide acetate</td>
<td>- Best excoriation penetration</td>
<td>- Ablery to use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Metabolic acidosis</td>
</tr>
<tr>
<td>Bacitracin</td>
<td>- Easy application</td>
<td>- Rare</td>
</tr>
<tr>
<td></td>
<td>- Good for superficial and facial burns</td>
<td></td>
</tr>
</tbody>
</table>

**Second Degree Burns**
- Occlusive dressings
  - May speed healing
  - Enhanced epithelialization and angiogenesis
  - Pain reduction (reduced dressing changes)
  - Improved cosmesis?
  - Fluid collections common and should be drained
  - Occlusive therapy does not increase infection rates
  - Hutchinson JJ. Wounds 1989;1:123
- Limit to small burns with minimal blistering

**Table 8. Occlusive Dressings.**

<table>
<thead>
<tr>
<th>Dressing</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duoderm</td>
<td>Easy and frequent wound assessment</td>
<td>Possible retention of fluid</td>
</tr>
<tr>
<td>Biobrane</td>
<td>Good wound adherence, can be removed frequently</td>
<td>Expanse</td>
</tr>
</tbody>
</table>

- Duoderm and Biobrane result in faster healing and less pain than silver sulfadiazine
- A recent study compared Duoderm to Biobrane
  - Both were equally effective
  - Duoderm was less expensive

Casidy et al. Burns 2005;31:990
Alternative Topical Therapies

- Silver salts (Acticoat)
- Aloe vera
  - Burns healed 6 days faster in 27 patients vs Vaseline
- Honey
- Potato skins
- Banana peals

Banana peals
Aloe vera
Silver salts (Acticoat)
Honey

Burns healed 6 days faster in 27 patients vs Vaseline

Third Degree Burns

- Do not heal spontaneously
- Require early excision and grafting
- Early referral and consultation with burn specialist required
- Wounds usually covered with autografts
- Skin substitutes for extensive or recalcitrant wounds

Table 1. Skin Substitutes.

<table>
<thead>
<tr>
<th>Type of skin substitute and percentage burned</th>
<th>Components</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidermal</td>
<td>Collagen, epidermis, granulation</td>
<td>2-in-1 wound dressing, high tensile strength</td>
<td>Temporary, limited flexibility</td>
</tr>
<tr>
<td>Dermagraft 3C</td>
<td>Collagen, granulation</td>
<td>Quick healing, high tensile strength</td>
<td>Temporary, limited flexibility</td>
</tr>
<tr>
<td>Autografts</td>
<td>Patient's own skin</td>
<td>Immediate tensile strength, high durability</td>
<td>Limited supply</td>
</tr>
<tr>
<td>Homograft</td>
<td>Human skin</td>
<td>Immediate tensile strength, high durability</td>
<td>Limited supply</td>
</tr>
</tbody>
</table>

Table 10. Burn Unit Referral Criteria.

1. Partial-thickness burns greater than 10% TBSA
2. Burns that involve the face, hands, feet, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
8. Any patients with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality
9. Burned children in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who will require special social, emotional, or long-term rehabilitative intervention

Indications for Admission

- Adults > 15% 2°
- Children > 10% 2°
- 3° burns > 2%
- Face, hands, feet, perineum
- Serious underlying diseases
- Social considerations

Follow Up Care

- Gently cleanse your burn twice daily with a mild soap and dry with a clean cloth or gauze.
- Apply antibacterial cream twice daily to the affected area and cover with bulky gauze dressing and wrap.
- Elevate all burned extremities.
- Report to your doctor or go to an emergency department if you develop increasing pain, redness, swelling, or a foul-smelling discharge from your burn or if you develop a fever and/or chills.
- You may take acetaminophen 500-1000 mg every 4-6 hours or ibuprofen 400-800 mg every 4-6 hours by mouth with food for pain.

Remember that the emergency department is open 24 hours a day, every day, and we are always glad to see you.
Long Term Complications

- Hypertrophic scarring, keloids, contractures
- Social and employment dysfunction
- Hyperpigmentation
- Most burn patients need follow up with specialist to consider rehabilitation

Electrical Burns

- Caused by passage of electric current
- Damage increased in small bony areas
  - Fingers, feet, lower legs, forearm
- Systemic effects
  - Low voltage (<1000 V): V Fib, NSSTT
  - High voltage (>1000): Massive tissue damage, respiratory and cardiac arrest
- ECG, CPK, UA, monitor
- Local care often necessitates grafting and amputation
- Consult burn specialist

Chemical Burns

- Delayed and progressive injury
- Deceptively superficial at first
- Acid more limited (coagulation necrosis)
- Alkalis more destructive (liquefaction)
- HFI: significant necrosis, arrhythmias, hypoCa
- Wet cement converts to CaOH
- Removal of causative agent
  - Brush off metals and powders
  - Copious irrigation with water
- Consult burn specialist
### Table 3. Summary Of Treatment Measures For Specific Chemical Burns.

- **Irrigation with water**
  - Most acids and alkali
  - Hydrocarbons
- **Topical or injectable calcium or magnesium salts**
  - Hydrofluoric acid
- **Cover burn with oil**
  - Sodium metal
  - Lithium metal
- **Special measures**
  - Sodium and lithium metals: brush away or excise pieces of metal
  - Phenol: polyethylene glycol wipe
  - White phosphorus: copper sulfate irrigation
  - Alkyl mercury agents: debride and remove blister fluid

### Table 5. Proposed Indications For Hyperbaric Therapy In CO Poisoning.

- CO level >25% (or >15% for pregnant women and young children)
- Myocardial ischemia
- Cardiac dysrhythmias
- Neuropsychiatric abnormalities or history of coma