Pediatric burns, Inhalational injury and Burn Toxicology

Kartik Pandya MD
Pediatric Surgery Fellow, Jan 26th 2015
Disclosures

- I have no disclosures
Learning Objectives

● Accurately assess and describe pediatric burns
● Understand inhalational injury associated with burns
● Understand burn resuscitation
● Assess for burn related metabolic derangements
Pediatric Burns

- ~1 million/year
- 50k burns are moderate/severe
- Majority in < 15 year old patients
- 2500 burn deaths/year
Layers of skin

Burn depth

Burn Nomenclature

Old way:
• 1st
• 2nd
• 3rd

New way:
• Superficial
• Partial thickness
• Deep partial thickness
• Full thickness
Depth examples

Zones of burn injury

SUPERFICIAL 2° BURN

Deep 2° Burn

Epidermis

Dermis

Subcutaneous tissue

Zone of coagulation

Zone of stasis

Zone of hyperemia

Zones of burn injury

- Local mediators: Thromboxane A2, bradykinin, leukotrienes, vasoactive amines, catecholamines, activated compliment system
- Organ effects: Lowered GFR and renal insufficiency, intestinal mucosa apoptosis
- Systemic effects: Low CO, capillary leak, angiotensin, aldosterone, vasopressin, immune suppression
Rule of “Nines”

Pediatric Burn Mortality

Table 1. Mortality among patients according to age, burn size, and presence or absence of inhalation injury.

<table>
<thead>
<tr>
<th>Percentage of Body-Surface Area Burned</th>
<th>Age (yr)</th>
<th>0–10</th>
<th>11–20</th>
<th>21–30</th>
<th>31–40</th>
<th>41–50</th>
<th>51–60</th>
<th>61–70</th>
<th>71–80</th>
<th>81–90</th>
<th>91–100</th>
</tr>
</thead>
<tbody>
<tr>
<td>No inhalation injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–20</td>
<td>0 (642)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>100</td>
</tr>
<tr>
<td>21–40</td>
<td>0 (46)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>41–60</td>
<td>0 (8)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>61–80</td>
<td>33 (3)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>81–100</td>
<td>0 (1)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Inhalation injury</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0–20</td>
<td>0 (17)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>21–40</td>
<td>0 (12)</td>
<td>25</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>41–60</td>
<td>14 (14)</td>
<td>50</td>
<td>20</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>61–80</td>
<td>33 (3)</td>
<td>20</td>
<td>0</td>
<td>75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>81–100</td>
<td>38 (8)</td>
<td>38</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>38</td>
<td>38</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

Percent mortality (number of patients at risk)
Burn mortality

- Related to:
  - TBSA of deep partial thickness to full thickness burns (> 30%)
  - Age (< 48 months)
  - Presence of inhalational injury
  - Resuscitation and in-hospital management
Management of the High-Risk Pediatric Burn Patient

By Robert L. Sheridan and Jay J. Schnitzer

Boston, Massachusetts

- Fluid titration to meet resuscitation goals
- Ventilator mgmt. for permissive hypercapnia
- Early excision and grafting
- 26 pts (< 2 yo, > 30% burn w/ inhalational injury over 9 yrs)
  - 1 excluded (98% burn)
  - 100% survival

## Burn Resuscitation

<table>
<thead>
<tr>
<th>Formula</th>
<th>First 24 hrs</th>
<th>Fluid Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parkland</td>
<td>4 mL/kg per % TBSA burn</td>
<td>Lactated Ringer’s</td>
</tr>
<tr>
<td>Brooke</td>
<td>1.5 mL/kg per % TBSA burn</td>
<td>LR + colloid 0.5 mL/kg per TBSA burn</td>
</tr>
<tr>
<td>Shriner’s Galveston</td>
<td>5000 mL/m2 burned + 2000 mL/m2 total</td>
<td>LR + 12.5 gm albumin</td>
</tr>
</tbody>
</table>

50% volume given in first 8 hours  
Add dextrose for patients < 2 years of age
## Indications for Transfer

**Table 13-3 -- Major Burn Injury Criteria (American Burn Association)**

<table>
<thead>
<tr>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Second-degree burns &gt; 10% TBSA in patients younger than 10 yr</td>
</tr>
<tr>
<td>Third-degree burns &gt; 5% TBSA</td>
</tr>
<tr>
<td>Burns involving the face, hands, feet, genitalia, perineum, and major joints</td>
</tr>
<tr>
<td>Chemical burns</td>
</tr>
<tr>
<td>Electrical burns including lightning injury</td>
</tr>
<tr>
<td>Inhalation injury</td>
</tr>
<tr>
<td>Burns with significant concomitant trauma</td>
</tr>
<tr>
<td>Burns with significant preexisting medical disorders</td>
</tr>
</tbody>
</table>
# Topical Antimicrobials

## Table 2: Topical Antimicrobial Agents Used in Burn Care

<table>
<thead>
<tr>
<th>Agent</th>
<th>Antimicrobial Coverage</th>
<th>Advantages</th>
<th>Disadvantages/Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacitracin</td>
<td>Gram-positive bacterial</td>
<td>Soothes and moisturizes; good for facial care and epithelializing wounds</td>
<td>Not appropriate for deeper wounds</td>
</tr>
<tr>
<td>Mafenide</td>
<td>Broad-spectrum antibacterial; anticostridial</td>
<td>Penetrates eschar well; available as solution or cream</td>
<td>Painful on application; causes metabolic acidosis (via carbonic anhydrase inhibition)</td>
</tr>
<tr>
<td>Mupirocin</td>
<td>Anti-MRSA</td>
<td>Effective against MRSA</td>
<td>Narrow (poor gram-negative) antimicrobial coverage</td>
</tr>
<tr>
<td>Nystatin</td>
<td>Antifungal (<em>Candida</em>)</td>
<td>Provides fungal prophylaxis with swish-and-swallow solution</td>
<td>May interfere with activity of mafenide</td>
</tr>
<tr>
<td>Silver nitrate</td>
<td>Broad-spectrum antibacterial</td>
<td>Effective for both prophylaxis and treatment of wound infection</td>
<td>Penetrates eschar poorly; causes hyponatremia; stains linen and dressings; induces methemoglobinemia</td>
</tr>
<tr>
<td>Silver sulfadiazine</td>
<td>Broad-spectrum antibacterial; antipseudomonal</td>
<td>Soothes on application and causes no pain</td>
<td>Penetrates eschar poorly; causes leukopenia</td>
</tr>
</tbody>
</table>
Topical antimicrobial side-effects

- Silver sulfadiazine (Silvadene)
  - Can cause leukopenia from margination and bone marrow suppression
  - Consider switching to alternative agent if WBC < 3000
- Mafenide acetate (Sulfamylon)
  - Carbonic anhydrase inhibitor causing metabolic acidosis
  - Mitigate by using only for 20% TBSA burn (rotating)
Other skin coverings

- Biobrane (superficial 2nd degree)
  - Bilaminate, semi permeable silicone, nylon fabric mesh with monomolecular layer of type 1 porcine collagen
  - Leave on for 24-48 hours
    - Initially adherent, comes off when skin re-epithelializes
- Many more...
<table>
<thead>
<tr>
<th>Table 13-5 -- Burn Wound Dressings</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dressings</strong></td>
</tr>
<tr>
<td><strong>Antimicrobial Salves</strong></td>
</tr>
<tr>
<td>Silver sulfadiazine (Silvadene)</td>
</tr>
<tr>
<td>Mafenide acetate (Sulfamylon)</td>
</tr>
<tr>
<td>Bacitracin/neomycin/polymyxin B</td>
</tr>
<tr>
<td>Nystatin</td>
</tr>
<tr>
<td>Mupirocin (Bactroban)</td>
</tr>
<tr>
<td><strong>Antimicrobial Soaks</strong></td>
</tr>
<tr>
<td>0.5% Silver nitrate</td>
</tr>
<tr>
<td>Povidone-iodine (Betadine)</td>
</tr>
<tr>
<td>5% Mafenide acetate</td>
</tr>
<tr>
<td>0.025% Sodium hypochlorite (Dakin’s solution)</td>
</tr>
<tr>
<td>0.25% Acetic acid</td>
</tr>
<tr>
<td><strong>Silver-impregnated</strong></td>
</tr>
<tr>
<td>Aquacel, Acticoat</td>
</tr>
<tr>
<td><strong>Synthetic Dressings</strong></td>
</tr>
<tr>
<td>Biobrane</td>
</tr>
<tr>
<td>Opsite, Tegaderm</td>
</tr>
<tr>
<td>Transcynel</td>
</tr>
<tr>
<td>Integra, Alloderm</td>
</tr>
<tr>
<td><strong>Biologic Dressings</strong></td>
</tr>
<tr>
<td>Allograft (cadaver skin), Xenograft (pig skin)</td>
</tr>
<tr>
<td>Amniotic membrane</td>
</tr>
</tbody>
</table>

Escharotomies
Excision and Grafting

- Early excision and grafting (< 24 hrs)
  - Less bleeding
  - Fewer procedures
  - Lower length of stay in hospital
  - Lower levels of pro-inflammatory mediators (IL-6 and TNFα in rats)


Burn Nutrition and Metabolism
Nutrition/Metabolism

● Burns are a hypermetabolic state
  ○ Insulin resistance and elevated glucagon, cortisol
    ▪ Hyperglycemia
    ▪ Negative nitrogen balance, loss of tissue protein

● Increased catecholamines
  ○ Tachycardia (causing heart failure)
  ○ Increased lipolysis (causing fatty infiltration of liver)
Metabolic agents

- rHGH (0.2 mg/kg/day)
  - Also used on conjunction with propranolol to decrease burn related catabolism
  - Can cause hyperglycemia and hypertriglyceridemia
- Oxandrolone (0.1 mg/kg/BID)
  - Like testosterone but lower androgenic/anabolic ratio
- Both contribute to shorter hospital stays, improved wound healing and increases in lean body mass
- Propranolol (to decrease HR by 15%)

Inhalational Injury
Inhalational Injury

- Closed space burns
- Upper airway
  - Highly efficient heat exchanger
  - Steam can travel to distant airways
- Lower airways
  - H₂O, SO₂, NO₂ leads to H₂SO₄ and H₂NO₃
- Reduction in cross-sectional area
Inhalational Injury

- Increases mortality (up to 40%)
- Vasoactive and pro-thrombotic agents cause fibrin casts
  - Cause ball-valve effect and barotrauma
- Pulmonary vasoconstriction (thromboxane A2, C3a, C5a)
- Bronchoscopy +/- Xe-133 scan (lung excretion)
Bronchoscopy

Inhalational Injury Mgmt.

- Pulmonary edema
  - Not decreased by fluid restriction
- Poor perfusion may sequester neutrophils and cause further pulmonary injury
- Things that don’t help
  - Corticosteroids
  - Prophylactic antibiotics
    - Early PNA: MRSA
    - Late PNA: Gram – organisms like Pseudomonas
Inhalational Injury Mgmt.

- ABC’s
- Stridor and hoarseness
  - Protect airway
- Supplementary O2 (for CO toxicity)
- Fluid supplementation
  - Additional 2 ml/kg/%TBSA burn
- Interlukins profile may predict inhalational burn mortality (↑ IL-6 and IL-10, ↓ IL-7)

Inhalational Injury Mgmt.

- Aggressive pulmonary toilet
- Bronchodilators
  - Albuterol q2hrs
- Inhaled heparin
- 5,000-10,000 u/3 mL normal saline q4hrs
- 20% n-Acetylcysteine
  - 3 mL q4hrs
- Hypertonic saline
- Racemic epinephrine
Burn Toxicology
Inhaled Toxins

- CO & CN disrupt cytochrome oxidase
- Profound metabolic acidosis
Carbon monoxide

- 240x greater affinity for Hgb
  - 0.1 ppm normal atmospheric level
  - 5,000 ppm in wood burning fire
- Suspect in all indoor fires
- Suspect with SaO2/PaO2 discrepancy
- Check COHgb level or use CO-oximeter
- Treat CO levels > 15%
  - Check ECG and cardiac enzymes
  - Give 100% O2
Carbon monoxide treatment

- COHgb half life dependent on [O2]
  - Half life at room air – 4-6 hours
  - 100% O2 at 1 atm – 60-90 mins
  - 100% O2 at 3 atm – 20-30 mins
- Use hyperbaric O2 if...
  - COHgb > 30% (>10% in pregnant women), severe neurologic sx, ECG shows ischemia or infarct, dysrhythmias, failure to improve after 4 hours on 100% at 1 atm
Cyanide

- CN binds cytochrome oxidase blocking oxidative phosphorylation
- Lactic acidosis
- High venous PO2
- Check cyanide levels
  - 0.5 – 1 mg/L: Tachycardia and flushing
  - 1 – 2.5 mg/L: Altered mental status
  - 2.5 – 3.0 mg/L: Coma
  - > 3.0 mg/L: Death
Cyanide Treatment

- **Sodium thiosulfate**
  - Donates sulfur groups to enzyme rhodanese
  - Rhodanese converts cyanide to thiocyanate (less toxic)
  - Thiocyanate excreted in urine (or via dialysis)
Cyanide treatment

- **Hydroxocobalamin**
  - Binds CN with greater affinity than Hgb
  - CN + Hydroxocobalamin = cyanocobalamin
  - Cyanocobalamin is non-toxic and excreted in urine
  - Give 70 mg/kg IV x1, may repeat with 35 mg/kg IV x1
  - No methemoglobinemia
Summary

- TBSA and inhalational injury associated with mortality
- Fluid and vent. management critical
- Nutritional support and metabolic regulation
- Burn-related toxic metabolites require prompt identification and treatment