Anesthetic Considerations for Pediatric Burn Patients

Marisa K. Bell MD, FAAP
Clinical Assistant Professor of Anesthesiology
Children’s Hospital Los Angeles
Keck School of Medicine of USC

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Disclosures:

No relevant financial relationships to disclose
Learning Objectives:

• Appreciate the global impact of burn injuries
• Describe basic burn characteristics
• Distinguish the two distinct phases of burn injury
• Recognize inhalational injury
• Identify the pharmacologic impact of burn injury
Global Impact:

- Majority of burns occur in children < 5 years old
- Majority of burn injuries occur in Africa, South-East Asia and the Eastern Mediterranean
- Over 95% of fire-related burns occur in low-middle income countries
- Fire-related burns account for 10 million disability adjusted life years lost each year
Burn Injuries: Gender Disparity

*Females have a higher rate of burn injuries*

- Open fire cooking
- Fossil fueled cookstoves
- Ground level cooking
What is a Burn?

A burn is an injury to skin or other organic tissue caused by

- Heat
- Radiation
- Radioactivity
- Electricity
- Friction
- Chemicals (acid)
- Smoke inhalation
Burns are described in terms of:

• Depth
• Total Body Surface Area
**Depth**

**Superficial:** limited to epidermis, typically does not require hospital management, heals within 7 days, looks like a bad sunburn

**Partial-Thickness:** damage extends to dermis, blistering, some heal without surgery, some require debridement and grafting, re-epithelialize within 14-21 days

**Full-Thickness:** dermis destroyed, insensate (the nerves get burned), will only heal with grafting
Total Body Surface Area (TBSA)

• Separate charts are used to estimate TBSA in children because of differences in body proportion.

• Children have proportionally larger heads, smaller legs, and smaller hands than adults.
Estimating Percent Total Body Surface Area in Children Affected by Burns

(A) Rule of "nines"
(B) Lund-Browder diagram for estimating extent of burns
(C) Palmar hand surface of the child is approximately 1% TBSA
When did the Burn Occur?

- The physiologic derangements associated with burns occur in 2 phases.
- The bigger the burn, the bigger the derangements.
The “Ebb” Phase: first 24-48hrs of burn injury

- Cerebral edema?
- Mental Status?
- ↑ Pain response

- Pulmonary edema
- Bronchospasm
- ARDS

- Myoglobinuria
- Oliguria

- Tachycardia
- Myocardial depression
- Decreased cardiac output
- Metabolic acidosis

- Aldosterone & Cortisol secretion

- Fluid loss through burned skin & generalized edema in > 25% TBSA burns

- Circumferential burns of limbs, chest, abdomen can cause compartment syndrome.
The “Flow” Phase: > 48hrs of burn injury

Cerebral edema?
Mental Status?
↑ Pain response

Pulmonary edema
Bronchospasm
ARDS

Altered metabolic function
Altered drug clearance
↑ Liver blood flow
↓ Albumin
↓ Clotting factors

Bone marrow depression

Tachycardia
Increased cardiac output
Increased oxygen consumption
Decreased SVR

↑ O2 consumption
↑ CO2 production
Muscle breakdown
Insulin resistance
Generalized edema with > 25% TBSA burn

↑ Renal blood flow
↓ Tubular function

Figure 7
Burns in Infants and Children

- Thinner skin
- Lose more fluid proportionately
- More prone to hypothermia
- Mount a greater systemic inflammatory response

Figure 8
The anesthetic management of infants and children with burns requires understanding the physiologic changes that occur from the moment of the burn until the wounds are healed.

Figure 9
Indications for Anesthesia:

Pediatric burn patients will present for
• Wound debridement
• Excision, grafting, & reconstruction
• Dressing changes

Figure 10
Pre-Operative Evaluation

Burns can be associated with

• Tracheobronchial injury
• Inhalational injury
• Multi-organ injury
• Contractures
• Hyperalgesia
• Allodynia
• Post-traumatic stress disorder
Pre-Operative Evaluation:

Is there inhalational injury?

• Steam and hot gases
• Toxic products from the fire
• Impairment of oxygen transport by inhalation of carbon monoxide and cyanide
Inhalational Injury

Recognition: singed nose hairs, soot at nose & mouth

Treatment: supportive respiratory care
• Airway management
• Lung-protective mechanical ventilation
• Aggressive pulmonary toilet

Clinical manifestations: delayed post-exposure
• Sloughing mucosa
• Cast formation causing atelectasis
• Bronchial obstruction and mucosal plugging
• Rarely manifest < 24hrs, evolve over 48-72hrs
Carbon Monoxide (CO) Inhalation

CO has higher affinity for hemoglobin (Hb) than oxygen
- CO binds to Hb to form carboxy-hemoglobin (COHb)
- Hb is then unavailable for O2 transport

The half-life of COHb is 4 hours on room air
- Reduced to 40-60 min on 100% oxygen
- **Treatment:** 100% oxygen, supportive care and hyperbaric oxygen if available
Cyanide Inhalation

Cyanide (CN) is produced by burning nitrogenous materials

- CN binds to mitochondria and prevents oxygen from making ATP
- Cells revert to *anaerobic metabolism*
- Lactic acid production causes metabolic acidosis

Suspect cyanide with anion gap metabolic acidosis

- **Antidotes:** hydroxocobalamin, amyl nitrate, sodium nitrite, sodium thiosulfate
- **Treatment:** supportive care
Procedure Location:

May need to provide anesthesia in the
• OR
• ICU
• Sedation Unit
• Bedside

*Does the patient need to be transported to a higher-level hospital?*
Procedure Location:

- Sedation outside of the OR is common, especially in limited resource settings
- Ideally, monitoring, $O_2$, suction, airway and rescue equipment should be available
- A qualified anesthesia provider should be capable of:
  - Administering anesthesia, sedation and analgesic medications
  - Monitoring vital signs
  - Managing the airway and cardiorespiratory status
  - Appropriate fluid management
Pre-Medication:

• Children with burns often require frequent multiple procedures that are painful
• Children with burns can display extreme anxiety and post traumatic stress disorder
• Premedication can help alleviate this anxiety and distress
# Pre-Medication:

<table>
<thead>
<tr>
<th>DRUG</th>
<th>DOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midazolam PO</td>
<td>0.5 mg/kg (max 20 mg)</td>
</tr>
<tr>
<td>Midazolam IV</td>
<td>0.05 – 0.1 mg/kg/dose (max 5 mg)</td>
</tr>
<tr>
<td>Midazolam Nasal</td>
<td>0.2-0.4 mg/kg (max 10mg)</td>
</tr>
<tr>
<td>Ketamine PO</td>
<td>5 mg/kg (max 200 mg)</td>
</tr>
<tr>
<td>Ketamine IM</td>
<td>3 - 5 mg/kg (max 200 mg)</td>
</tr>
<tr>
<td>Ketamine IV</td>
<td>0.5-2 mg/kg (max 200mg)</td>
</tr>
<tr>
<td>Dexmedetomodimine Nasal</td>
<td>3 - 5 mcg/kg (max 200 mcg)</td>
</tr>
</tbody>
</table>
Induction Considerations

• Distraction techniques and a quiet, soothing environment without bright lighting can be helpful

• An inhalational induction with parental presence could be offered in an induction room or operating room.
Anesthetic Technique

• There are no specific agents nor techniques that are proven to be superior for burn anesthesia

• Regional, general, and local anesthesia can all be utilized

• Airway management:
  - Natural airway, nasal cannula, facemask
  - Nasal airway, Oral airway
  - LMA and ETT
# Anesthetic Technique

<table>
<thead>
<tr>
<th>Anesthetic Technique</th>
<th>MILD SEDATION</th>
<th>MODERATE SEDATION</th>
<th>DEEP SEDATION</th>
<th>GENERAL ANESTHESIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPONTANEOUS VENTILATION</td>
<td>Unaffected</td>
<td>Adequate</td>
<td>Intervention might be required</td>
<td>Intervention required</td>
</tr>
<tr>
<td>AIRWAY</td>
<td>Unaffected</td>
<td>No intervention required</td>
<td>Intervention might be required</td>
<td>Intervention often required</td>
</tr>
<tr>
<td>RESPONSIVENESS</td>
<td>Responds normally to verbal stimulation</td>
<td>Responds purposefully to verbal/tactile stimulation</td>
<td>Responds to deep/painful stimulation</td>
<td>Unarousable</td>
</tr>
<tr>
<td>CARDIOVASCULAR FUNCTION</td>
<td>Unaffected</td>
<td>Typically maintained</td>
<td>Typically maintained</td>
<td>Might require intervention</td>
</tr>
</tbody>
</table>
Anesthetic Agents to Minimize:

<table>
<thead>
<tr>
<th>Anesthetic Agent</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrous Oxide</td>
<td>Repeated and prolonged use can precipitate pernicious anemia in children with poor nutritional status</td>
</tr>
<tr>
<td>Etomidate</td>
<td>Repeated use can cause adrenal suppression</td>
</tr>
<tr>
<td>Haloperidol</td>
<td>Can cause extra-pyramidal symptoms and neuroleptic malignant syndrome</td>
</tr>
</tbody>
</table>
Fluid Resuscitation

• Burn edema is maximal in the first 18 - 30 hours
• IV fluid resuscitation is essential for supporting intravascular volume and perfusion
• Formulas based on body weight (i.e. Parkland Formula) likely underestimate resuscitation in children
• Endpoints such as capillary refill, mental state, and urine output should be followed
Intra-Operative Considerations

- Active warming will likely be needed
- Monitoring can be difficult
- Sites for peripheral intravenous access may be limited
- Significant blood loss during burn debridement procedures

Figure 12
Pharmacologic Considerations Unique to Burn Patients
Succinylcholine

Upregulation of extra-junctional acetylcholine receptors occurs in skeletal muscle after the acute phase

• In the first 24 – 48 hours it is safe to use succinylcholine in these patients

• After the first 24 - 48 hours succinylcholine can lead to *life threatening hyperkalemia*
Non-Depolarizing Muscle Relaxants (NDMRs)

• Due to the upregulation of extra-junctional acetylcholine receptors, patients in the hypermetabolic phase (after 24 – 48 hours), show resistance to NDMRs

• Higher and more frequent dosing of rocuronium or vecuronium are needed
Hypermetabolic Phase

• Increased drug clearance because of increased hepatic and renal blood flow; may need to re-dose medications more frequently

• Production of alpha-1-glycoprotein increases as it is an acute phase reactant which may decrease the free fraction of medication; may need larger doses
Pain Management

• Hyperalgesia
• Neuropathy
• Regeneration of peripheral nerves can result in paresthesia and opioid resistant neuropathic pain
  • consider gabapentin
• Tolerance to narcotics often develops and requires larger doses
Pain Management (con’t)

Procedures such as daily debridements and dressing changes can be intensely painful and often require multimodal approaches to pain management

• Narcotics: fentanyl, morphine, hydromorphone
• Opioid agonists/antagonists
• Methadone
• Ketamine and/or clonidine
• Regional anesthesia if possible
Conclusions:

• Burn injuries have a significant global impact
• Burns are described in terms of depth and total body surface area
• The “Ebb” and “Flow” phases have distinct pharmacological impact
• Inhalational injuries include carbon monoxide and cyanide poisoning.
• There are unique pediatric considerations
References:


Figures:


4. Wikimedia Commons, “Burns”, BruceBlaus, 3 November 15, CC-BY-SA-4.0. CC-BY-SA-4.0


6. Creative Commons, “Man Shadow with organs”, Mikael Haggstrom, CCO 1.0.

7. Creative Commons, “Female shadow with organs”, Mikael Haggstrom, CCO 1.0.
Figures (continued):

8. Creative Commons, “Soup burn – 2 days later”, Quasimime, CC BY-NC-ND-2.0.


