Principles of Anesthetic Care for Burned Children: an overview

Kenneth T. Furukawa, MD
Health Sciences Clinical Professor
Disclosure

The speaker has disclosed no relevant financial relationships with commercial interests related to this CME activity.

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Off-label Use Disclosure

Some medications mentioned in this presentation are not FDA approved for use in children in the manner suggested by the speaker.

- Inhaled heparin
Objectives

Upon completion of this session, the participant will be able to:
* Identify and manage the burned child with a compromised airway, including various components for inhalational injury.
* Recognize how burn injury affects drug pharmacodynamics and pharmacokinetics.
* Identify the unique challenges of anesthetic management of the child with burns.
Phases of burn care

- Emergent/resuscitation
  - Injury onset to fluid resuscitation completion
  - 0 – 3 days
  - Resuscitation, treat burn shock

- Acute
  - Diuresis from fluid resuscitation until wound closure
  - Duration of weeks to months
  - Achieve wound closure, support recovery

- Rehabilitation
  - Wound closure to optimal recovery
Case 1: Initial evaluation

- Called to assist with evaluation & management of child with facial burns from a closed space fire.
- Child cries, but hoarse.
- Moderate inhalation obstruction.
- What do you see here that suggests inhalation injury?
Case 1: Emergent/resuscitation phase care

- Airway management as indicated during initial and secondary surveys
  - Administer oxygen for presumed carboxyhemoglobinemia!
  - Assessment of airway & breathing
  - Face: skin burn lips, nose, face
  - Hair: singed eyebrows, nasal
  - Mouth: tongue swelling?
Case 1: Identify airway / inhalation injury

- Evaluate mouth, pharynx, glottis when possible.
- Laryngoscopy (indirect or direct) is indicated as part of suspicious airway evaluation.
  - Direct heat transfer/burn from hot air/gas/steam
- Is intubation or other airway support indicated?
Bronchoscopy evaluation if possible

- **Grade 0** no injury
- **Grade 1** mild injury
  - patchy erythema, carbonaceous deposits
- **Grade 2** moderate injury
  - moderate erythema, carbon, bronchorrhea, bronchial compromise
- **Grade 3** severe injury
  - severe inflammation, friable, copious carbon and bronchorrhea, bronchial obstruction
- **Grade 4** massive injury
  - sloughing, necrosis, obliteration

Massive inhalation injury
Burned airway risks

- Rapid edema
  - Thermal damage, toxins

- Resuscitation related airway edema may develop over 24+ hours
  - Continuous monitoring with on-site expert management or early intubation

- Impaired oxygenation
  - Carboxyhemoglobin, cyanide, edema, tissue damage

- Increased deadspace
  - Alveolar & distal airways damage/obstruction

- Increased risk of pneumonia

- Association with ARDS and other ventilator induced lung injuries
Intubation is not always indicated but ...

- However delayed edema may exacerbate airway obstruction
  - Observe for at least 24 hours!
  - Glottic edema may present similar to epiglottitis

- Plan for difficult airway management and airway swelling
  - Bronchoscopy evaluation offers opportunity to intubate immediately if desired
  - IV ketamine helpful for spontaneous ventilation and sedation/analgesia

- 10-30% of hospitalized burn patients have inhalation/airway injury with related mortality of 16+%%
  - 25-50% of these die if require ventilator support for more than 1 week
Case 1: Intubation indicated?

- What about our case?
  - Facial/nasal hair singed
  - Voice change
  - Glottic edema
  - Bronchoscopy likely to demonstrate at least mild injury to upper trachea

- Yes, let’s secure the airway!
Case 1: Intubation choices

- Oral vs nasotracheal
  - Oral intubation often simpler
  - Nasotracheal more secure (personal preference)

- Cuffed ETT
  - Size & place carefully due to acute edema

- Secure carefully...there will be swelling!
  - Tape will work loose due to secretions and topical Rx
  - Circumferential tape/twill will cut unless loosened often
  - Will need to be tightened periodically as swelling reduces!
  - Consider alternate securement techniques

- Re-intubation may be a lethal procedure!
Securing ETT and Facial Burns

- Oral ETT with 4 point tape
- Note pressure to swollen scalp, ear, neck
  - Needs constant adjustment
- Topical ointment compromises adhesive
- Large area of tissue injured by tape

Four point tape harness
Protect face from pressure of twill on ETT

- Plastic tubing reduces friction
- Adjust for swelling at side
  - Loosen or tighten as needed
- Vertical strap separate

Note facial/nasal edema & loss nasal hairs
Oral ETT Secured with Wire

- Secure around tooth
- Deciduous teeth do come out!
- Wire suture can be used around root of teeth

Wire tied around tooth
Secure nasotracheal ETT behind nasal septum

- Nasotracheal ETT in place
- Two “rubber” catheters placed naso-orally & brought out mouth
- Long twill tied to both catheters
Secure nasotracheal ETT behind nasal septum

- Withdraw catheters & twill through nose
- Secure ETT with some give to internal twill around septum & nasopharynx.

Catheters withdrawn through nose, twill then tied to ETT from each nare.
Case 1: Inhalation injury management

- High flow, humidified oxygen ... Carboxyhemoglobinemia likely!
  - Reduced PaO2 despite normal SpO2
  - Use co-oximetry or multiple wavelength near-infrared pulse oximeter
  - 100% O2 reduces COHb half-life from 4 hr to <1 hr.

- Check ABG with co-oximetry frequently
  - Follow carboxyhemoglobin concentration/percentage
Case 1: Inhalation injury management cont.

- Persistent signs of hypoxemia ... consider cyanide toxicity from burning synthetics
  - Tachycardia, tachypnea, hypertension
  - Anion gap metabolic acidosis despite adequate PaO2, SvO2 may be elevated
  - Hydroxycobalamin 5gm IV over 15 min adult
Case 1: Ventilation management

- No definite data suggesting best strategy to date:
  - Lung protective low Vt (6ml/kg) with low PEEP vs higher Vt (12-15ml/kg) with PEEP to minimize FiO2
    - Lung protective/ARDS preventive strategy accepted despite little data in pediatric burns
  - PCV vs VCV
  - HFPV (high frequency percussive ventilation) oscillator superimposed over PCV
    - May have better PaO2 and PaCO2 with lower Pinsp than PCV techniques
    - Less barotrauma compared to low Vt strategy?
Ventilator strategy comparison

- Is inhalation injury similar to other forms of ARDS?
  - Lung injury is thermal, chemical, and inflammatory.
  - Early & copious sloughing in severe cases.
  - Initially lung protective strategies
  - Alternates tend to higher Vt & PEEP first, then HFPV (VDR)

Goh CT, Jacobe S 2015
Holland D, Wolf SE, etal 2013
Jeschke MG, Herndon DN 2014

Figure 1. Simplified pressure time waveform depicting the various forms of ventilation used in inhalation injury (see text for explanation).
Adjuncts for inhalation injury

- Inhaled nitric oxide
  - Limited data as rescue therapy for inhalation injury

- Inhaled heparin +/- N-acetylcystiene
  - Limited data
  - Reduce fibrin deposition, cast formation in bronchial structures
  - Improve expectoration

- Inhaled epinephrine, albuterol, ipratropium
  - Bronchodilation and anti-inflammatory

- No role for preemptive antibiotics or steroid

Miller AC, Elamin EM, Suffredini AF 2014
Tracheostomy

- Institution practice specific
- Some indications for early after resuscitation & diuresis
  - Anticipated ventilator support for more than 2 weeks
  - High risk of extubation and difficult reintubation
  - Allows earlier face sheet grafting without ETT securement trauma
Case 2: Pharmacokinetics and pharmacodynamics in burns

- Multiple physiologic alterations occur with moderate to severe burn injuries greatly impacting upon expected pharmacokinetic and pharmacodynamic profiles of all medications.
- In fact, the response to IV ketamine was more profound than expected, and the patient is moving 20 minutes after IV rocuronium 0.6 mg/kg.
- What is happening?
Pharmacokinetic changes throughout emergent & acute burn care phases

- Plasma albumin loss
  - Reduced binding, increased free fraction

- Alpha 1 acid glycoprotein acute phase reactant increases
  - Increased binding of cationic medications

- Volume of distribution increased
  - Fentanyl, morphine, propofol, ketamine, NMBs
Pharmacokinetic changes: “Burn Shock” emergent/resuscitation period

- Cardiac output reduced
  - Inflammatory mediated cardiomyopathy?
- Hepatic & renal blood flow reduced
- Drug clearance reduced
  - Adequate fluid resuscitation reduces impact but increases general edema formation
  - Inadequate resuscitation risks further organ damage and prolonged shock state
Pharmacodynamic changes: acute phase

- After successful resuscitation, diuresis begins and the patient enters a prolonged “hyperdynamic” phase
  - Inflammatory mediated responses
  - Increased cardiac output
  - Increased hepatic and renal blood flow
  - Increased drug clearance
  - Increased activity hepatic isoenzyme systems
Pharmacodynamic changes: acute phase

- Hepatic enzymatic activity altered
  - Phase 1 reactions (oxidation, reduction, hydroxylation, demethylation) reduced
  - Phase 2 (conjugation, glucoronidation) unchanged?
Neuromuscular blocking agents: acute phase

- Depolarizing agent (succinylcholine) induced hyperkalemia
  - Acetylcholine receptor upregulation begins immediately
  - May be significant > 1 year after all wounds closed

- Nondepolarizing agents decreased sensitivity / increased resistance (all classes)
  - Acetylcholine receptor upregulation
  - Increased plasma binding to alpha acid glycoprotein
  - Increased hepatic & renal clearance
Anesthetic/sedative agents: acute phase

- Volume of distribution increased
- Hepatic & renal clearance increased
- **Tolerance may be marked**
  - Adjunctive agents may “modify” this situation
Opioids: acute phase

- Possibly more remarkable tolerance than other agents
  - But it appears that burn patients develop tolerance to all drugs.

- Down regulation of spinal $mu$-opioid receptors
  - Relative resistance to central opioid activity

- Upregulation of NMDA and protein kinase receptors
  - These receptors are implicated in opioid induced hyperalgesia mechanisms.
Adjuncts (sedation, analgesia, anxiety)

- NMDA receptor antagonists
  - Ketamine
  - Methadone
- Alpha-2 central catecholamine agonists
  - Clonidine
  - Dexmedetomidine
- “Anti-neuropathic” agents
  - Anti-epileptics (gabapentin, pregabalin, oxcarbazepine)
  - Anti-depressants (TCAs, SNRIs, SSRIs)
- Anti-histaminergic agents
Ketamine is unique

- Dissociative anesthetic induction/maintenance agent
  - Caution for emergence dysphoria/delirium
  - Secretion management
  - Chronically sympathomimetic activated patient may have primarily sympatholytic response
  - Maintains hypoxic & hypercapneic responses during spontaneous ventilation
  - Modifies tolerance to other analgesic agents
Regional anesthesia/analgesia: all phases

- Limited role for regional anesthesia in large TBSA interventions, but very useful for smaller interventions
  - Fascia iliaca compartment block for thigh STSG donor site

- Local anesthetic in tumescent solution injected for wound debridement and STSG donor harvest.

- Central neuraxial, peripheral nerve blocks, truncal blocks single shot and continuous
  - Presumed increased infection risk when performed through or near burned tissues.
  - Local anesthetic altered pharmacokinetics?
Understanding Anesthetic Care in Terms of the Phases of Burn Care

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Emergent/resuscitation phase care

- Fluid and blood management per ATLS protocols, plus burn resuscitation guidelines (modified Parkland formula)
  - Parkland: LR 4 ml/kg/% burn over 24hr, 50% during 8 hrs
  - 20kg child w/ 40% TBSA 2\textsuperscript{nd}/3\textsuperscript{rd} burns: 3200ml LR in 24hrs, 1600ml in first 8 hrs
  - Goals hemodynamic stability, u/o 1ml/kg/hr
- Requires good vascular access
- Risks burn compartment syndromes
Extremity/chest/abdominal compartment syndromes: eschar/fascia/laparotomy

Arm escharotomy, leg escharotomies and fasciotomy, abdominal silo
Burn shock

- Cytokine mediated with possible cardiomyopathy
- Increased SVR and PVR
- Generalized edema may encourage hemoconcentration
- More likely burns >25% TBSA

Generally improves with fluid infusion
- Avoid vasopressors in favor of inotropes
Prevent heat loss

- Heat loss amplified due to destruction of intact skin
  - Radiation, evaporation, convection, conduction

- Most effective measure is high room temperature (as near 37C as tolerable)
  - Use blankets, thermal shielding, plastic wraps, etc.
  - Be wary of forced air warming and contact warming devices (water circulating mattress/blanket)

- Hypothermia the “first” leg in the Trauma Triad of Death
  - Hypothermia, acidosis, coagulopathy
Operative blood management

- Estimating blood loss during burn excision/dressing difficult
  - Multiple estimates developed:
    - 0.75ml/sq cm burned skin excised
    - 117ml/BSA% excised for adults (approx 2ml/kg/BSA%)
    - 2.6-3.4% BV/BSA%

- Blood product replacement must include adequate FFP and platelets
  - Consider massive transfusion protocol for excision > 20% TBSA
  - Blood loss continues after skin coverage and dressings

- Tourniquets, topical vasoconstrictors/thrombin are helpful but inadequate
Hypermetabolism

- Altered glucose, lipid, aminoacid/protein metabolism
  - Catabolism
  - Insulin resistance
  - Multi-organ dysfunction

- Appropriate enteral feeding limits catabolism
  - Post-pyloric enteral feeding should continue intraoperatively if well-tolerated
Airway challenges in rehabilitation phase

- Contractures are common
- Be prepared for unusual
- Maintain spontaneous ventilation if at all possible

Burn scar contractures create difficult airway
Pain management

- Opioid tolerance/hyperalgesia
  - NMDA antagonists
  - Antidepressants
  - Antiepileptics
  - Central alpha 2 agonists
- Benzodiazepine cautions
- APAP/NSAID ceiling effects
- Psychological management
Thanks

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References

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- Goh CT, Jacobe S. Ventilation Strategies in Paediatric Inhalation Injury. Paediatr Respir Rev 2015; Article in Press. [http://dx.doi.org/10.1016/j.prrv.2015.10.005](http://dx.doi.org/10.1016/j.prrv.2015.10.005)