Pediatric burns, Inhalational injury and Burn Toxicology

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Pediatric Surgery Fellow, Jan 26th 2015

Disclosures

- I have no disclosures

Learning Objectives

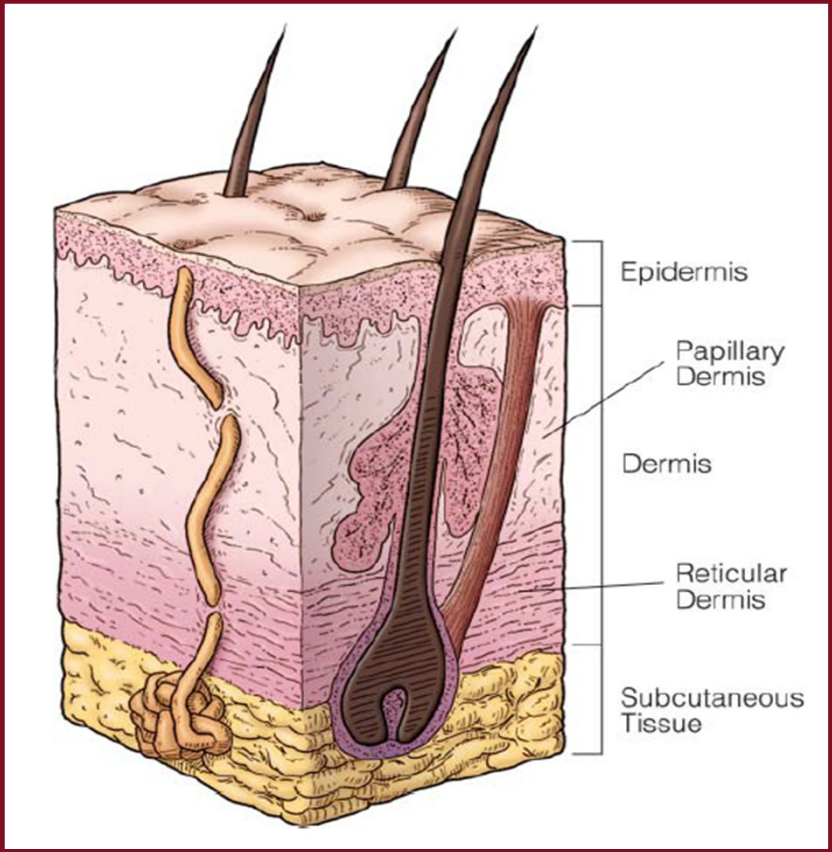
- Accurately assess and describe pediatric burns
- Understand inhalational injury associated with burns
- Understand burn resuscitation
- Assess for burn related metabolic derangements

Pediatric Burns

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

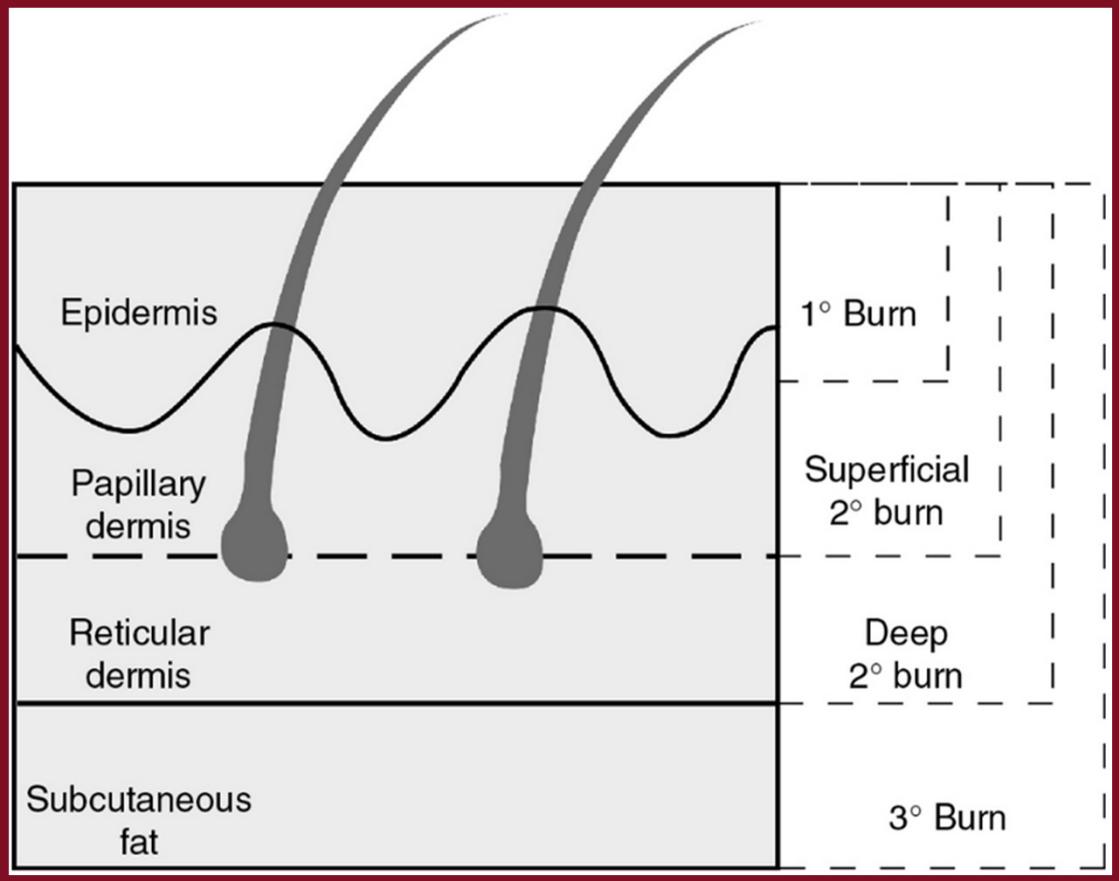
G.W. Holcomb III, Murphy JP. Burns, Ashcraft's Pediatric Surgery, G.W. Holcomb III, J.P. Murphy (Eds.)Saunders Elvesier, Philadelphia, PA (2009), pp. 154–166

Layers of skin



Sterling, JP., Heimbach, DM., Gibran NS., Management of the Burn Wound, ACS Surgery. Decker, 2010, pp. 1-13

Burn depth



Chung DH, Colon NC, Herndon DN. Chapter 26 - Burns. In: Coran AG, editor. Pediatric Surgery (Seventh Edition), Philadelphia: Mosby; 2012, p. 369–84.

Burn Nomenclature

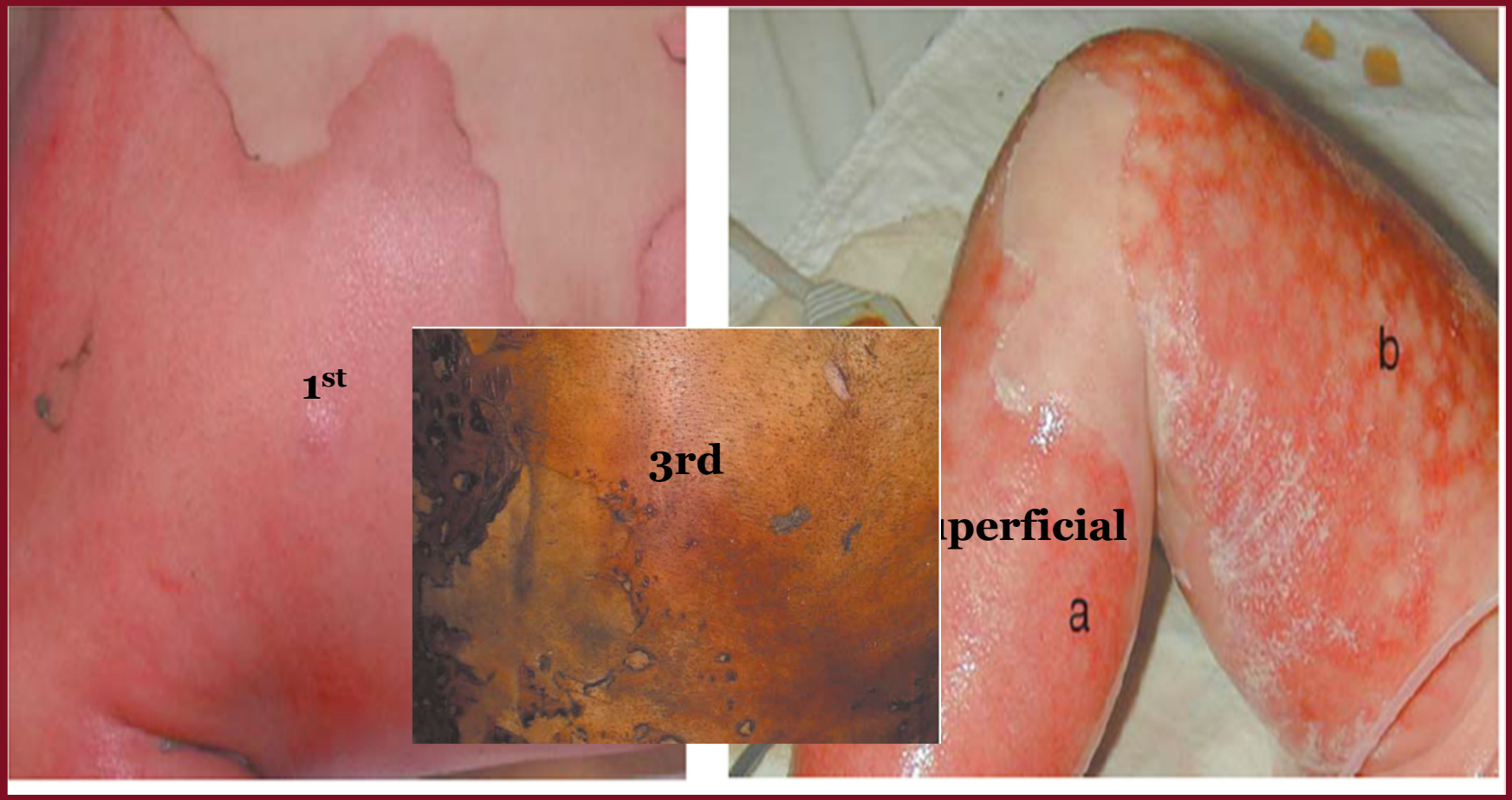
Old way:

- 1st
- 2nd
- 3rd

New way:

- Superficial
- Partial thickness
- Deep partial thickness
- Full thickness

Depth examples



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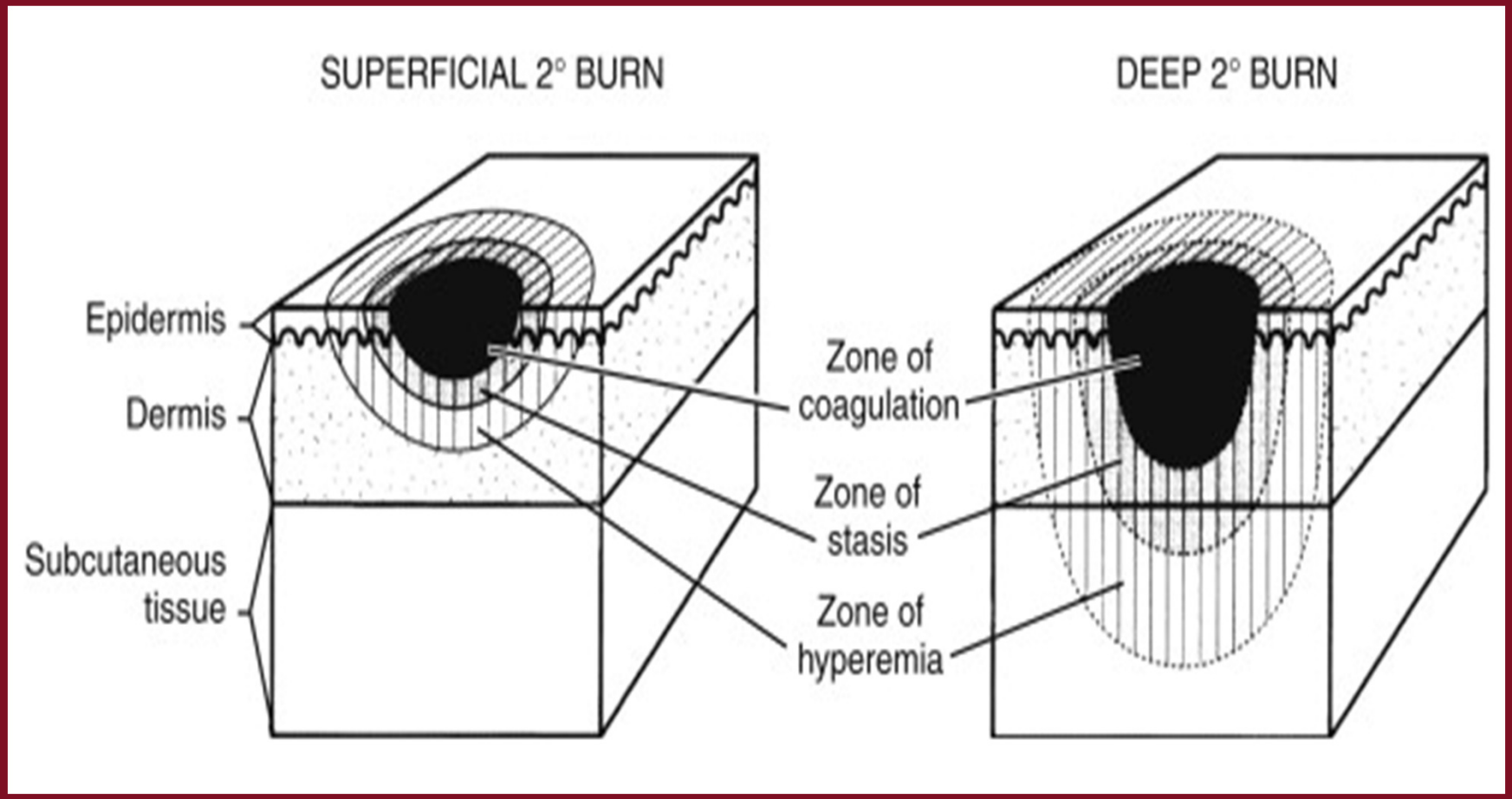
Zones of burn injury



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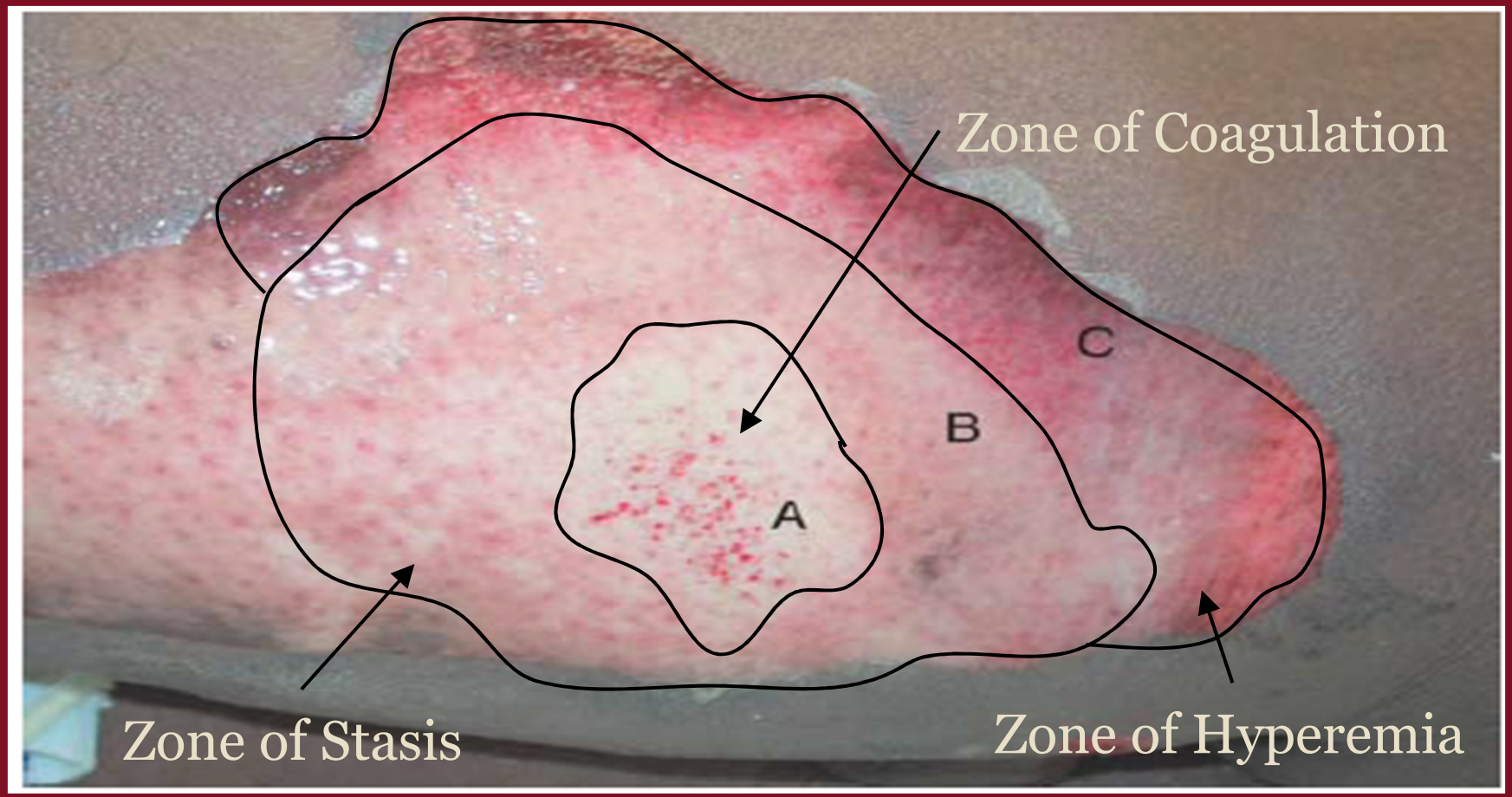
Zones of burn injury

- 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



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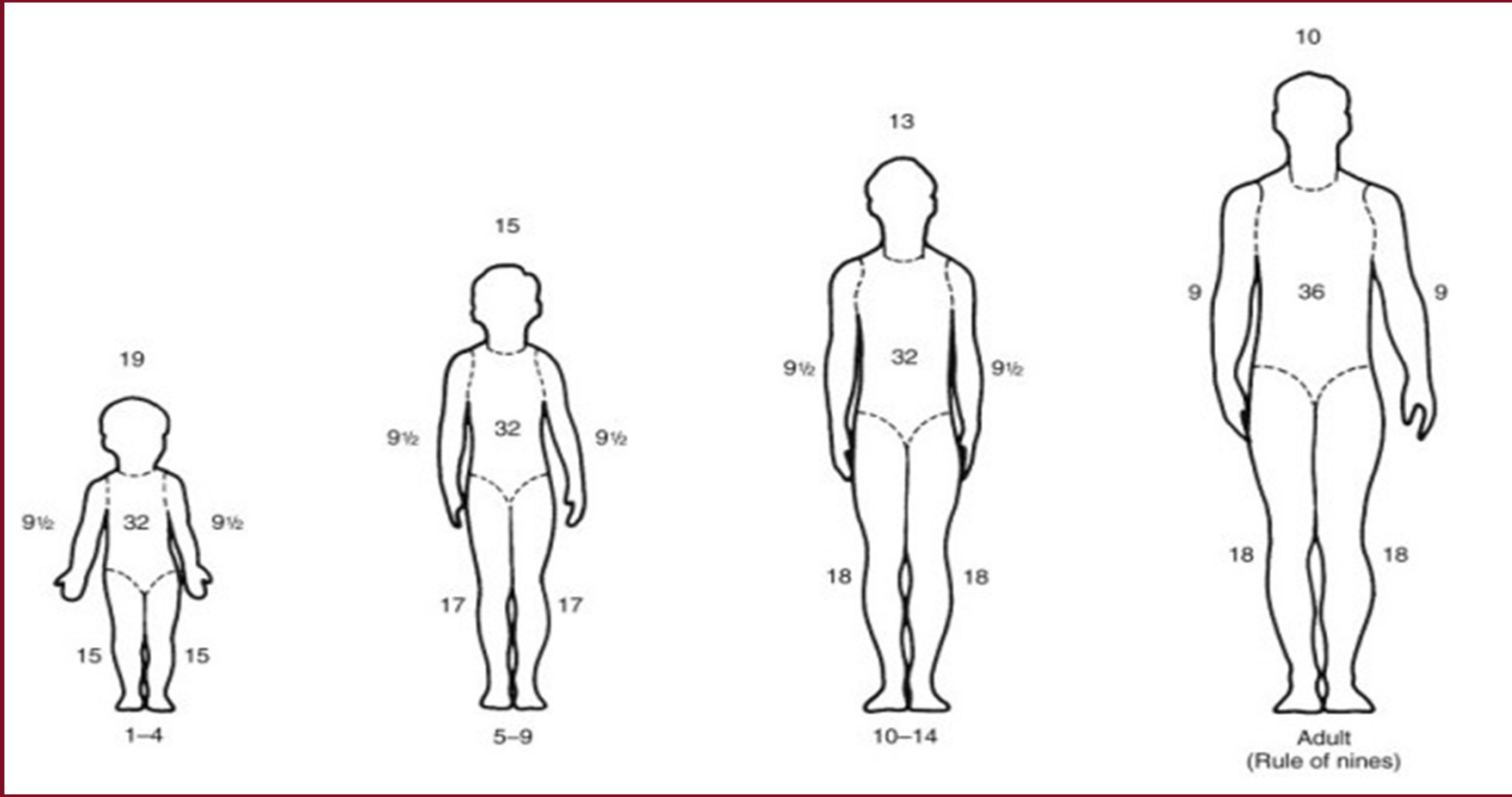
Rule of “Nines”



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Pediatric Burn Mortality

OBJECTIVE ESTIMATES OF THE PROBABILITY OF DEATH FROM BURN INJURIES

TABLE 1. MORTALITY AMONG PATIENTS ACCORDING TO AGE, BURN SIZE, AND PRESENCE OR ABSENCE OF INHALATION INJURY.

PERCENTAGE OF BODY-SURFACE AREA BURNED	AGE (YR)									
	0–10	11–20	21–30	31–40	41–50	51–60	61–70	71–80	81–90	91–100
	percent mortality (number of patients at risk)									
No inhalation injury										
0–20	0 (642)	0 (160)	1 (162)	1 (139)	1 (87)	0 (36)	0 (32)	0 (18)	8 (13)	100 (2)
21–40	0 (46)	0 (11)	0 (17)	0 (7)	0 (6)	0 (2)	0 (6)	0 (2)	100 (1)	—
41–60	0 (8)	0 (7)	0 (4)	—	0 (3)	0 (1)	—	0 (1)	—	—
61–80	33 (3)	0 (1)	0 (1)	—	—	0 (1)	—	—	—	—
81–100	0 (1)	—	—	—	0 (1)	—	—	—	—	—
Inhalation injury										
0–20	0 (17)	0 (10)	0 (11)	0 (13)	33 (3)	50 (2)	67 (3)	0 (4)	0 (2)	100 (1)
21–40	0 (12)	25 (4)	0 (11)	15 (13)	0 (13)	0 (3)	17 (6)	63 (8)	43 (7)	—
41–60	14 (14)	0 (7)	50 (4)	20 (5)	50 (6)	50 (2)	100 (3)	80 (5)	100 (2)	100 (1)
61–80	33 (3)	20 (5)	—	0 (3)	75 (4)	—	100 (1)	100 (2)	100 (1)	—
81–100	38 (8)	38 (8)	0 (1)	0 (2)	0 (3)	33 (3)	80 (5)	100 (2)	100 (1)	—

Ryan CM, Schoenfeld DA, Thorpe WP, Sheridan RL, Cassem EH, Tompkins RG. Objective estimates of the probability of death from burn injuries. New England Journal of Medicine 1998;338:362–6.

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

Sheridan RL, Schnitzer JJ. Management of the high-risk pediatric burn patient. Journal of Pediatric Surgery 2001;36:1308–12. doi:10.1053/jpsu.2001.25805.

Burn Resuscitation

Formula	First 24 hrs	Fluid Solution
Parkland	4 mL/kg per % TBSA burn	Lactated Ringer's
Brooke	1.5 mL/kg per % TBSA burn	LR + colloid 0.5 mL/kg per TBSA burn
Shriner's Galveston	5000 mL/m2 burned + 2000 mL/m2 total	LR + 12.5 gm albumin

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)

Second-degree burns > 10% TBSA in patients younger than 10 yr
Third-degree burns > 5% TBSA
Burns involving the face, hands, feet, genitalia, perineum, and major joints
Chemical burns
Electrical burns including lightning injury
Inhalation injury
Burns with significant concomitant trauma
Burns with significant preexisting medical disorders

G.W. Holcomb III, Murphy JP. Burns, Ashcraft's Pediatric Surgery, G.W. Holcomb III, J.P. Murphy (Eds.)Saunders Elvesier, Philadelphia, PA (2009), pp. 154–166

Topical antimicrobials

Table 2 **Topical Antimicrobial Agents Used in Burn Care**

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

Sterling, JP., Heimbach, DM., Gibran NS., Management of the Burn Wound, ACS Surgery. Decker, 2010, pp. 1-13

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 13-5 -- Burn Wound Dressings

Dressings	Advantages	Disadvantages
Antimicrobial Salves		
Silver sulfadiazine (Silvadene)	Painless; broad-spectrum; rare sensitivity	Leukopenia; some gram-negative resistance; mild inhibition of epithelialization
Mafenide acetate (Sulfamylon)	Broad-spectrum; penetrates eschar; effective against *Pseudomonas*	Painful; metabolic acidosis; mild inhibition of epithelialization
Bacitracin/Neomycin/Polymyxin B	Ease of application, painless, useful on face	Limited antimicrobial property
Nystatin	Effective in inhibiting fungal growth; use in combination with Silvadene, Bacitracin	Cannot use in combination with mafenide acetate
Mupirocin (Bactroban)	Effective against *Staphylococcus*, including MRSA	Cost; poor eschar penetration
Antimicrobial Soaks		
0.5% Silver nitrate	Painless; broad-spectrum; rare sensitivity	No eschar penetration; discolors contacted areas; electrolyte imbalance; methemoglobinemia
Povidone-iodine (Betadine)	Broad-spectrum antimicrobial	Painful; potential systemic absorption; hypersensitivity
5% Mafenide acetate	Broad-spectrum antimicrobial	Painful; no fungal coverage; metabolic acidosis
0.025% Sodium hypochlorite (Dakin's solution)	Effective against most organisms	Mildly inhibits epithelialization
0.25% Acetic acid	Effective against most organisms	Mildly inhibits epithelialization
Silver-impregnated		
Aquacel, Acticoat	Broad-spectrum antimicrobial; no dressing changes	Cost
Synthetic Dressings		
Biobrane	Provides wound barrier; minimizes pain; useful for outpatient burns, hands (gloves)	Exudate accumulation risks invasive wound infection; no antimicrobial property
OpSite, Tegaderm	Provides moisture barrier; minimizes pain; useful for outpatient burns; inexpensive	Exudate accumulation risks invasive wound infection; no antimicrobial property
Transcyte	Provides wound barrier; accelerates wound healing	Exudate accumulation risks invasive wound infection; no antimicrobial property
Integra, Alloderm	Complete wound closure, including dermal substitute	No antimicrobial property; expensive; requires training, experience
Biologic Dressings		
Allograft (cadaver skin), Xenograft (pig skin)	Temporary biologic dressings	Requires access to skin bank; cost
Amniotic membrane	Minimizes dressing changes	Not widely used

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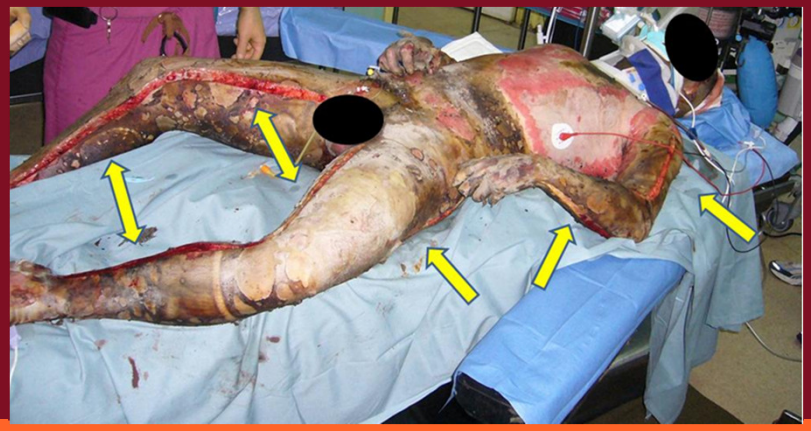
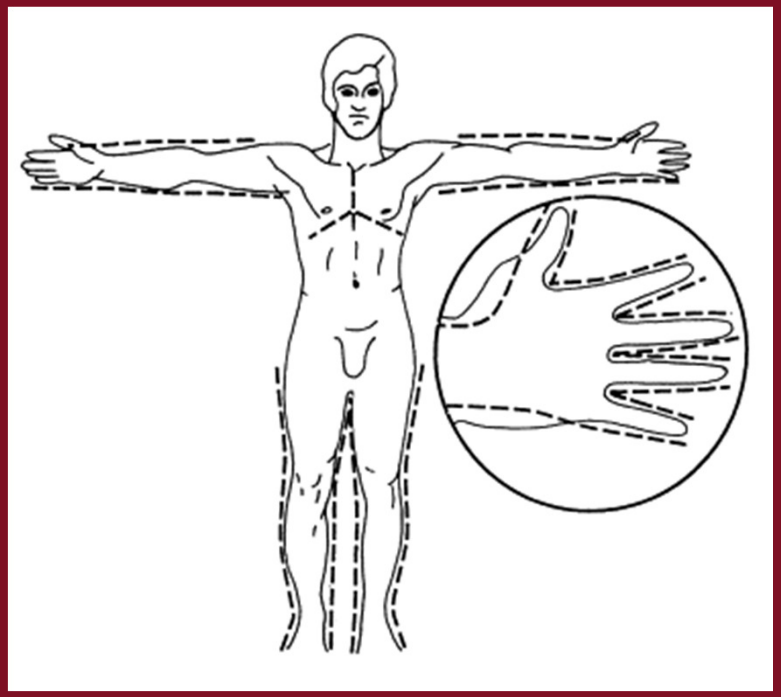
Escharotomies





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 TNFa in rats)

D.N. Herndon, D.H. Parks. Comparison of serial debridement and autografting and early massive excision with cadaver skin overlay in the treatment of large burns in children J Trauma, 26 (1986), pp. 149–152

X.L. Chen, Z.F. Xia, D.F. Ben, et al. Effects of early excision and grafting on cytokines and insulin resistance in burned rats Burns, 36 (2010), pp. 1122–1128

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%)

D.A. Gilpin, R.E. Barrow, R.L. Rutan, et al.: Recombinant human growth hormone accelerates wound healing in children with large cutaneous burns. Ann Surg. 220:19-24 1994
M.G. Jeschke, C.C. Finnerty, O.E. Suman, et al.: The effect of oxandrolone on the endocrinologic, inflammatory, and hypermetabolic responses during the acute phase postburn. Ann Surg. 246:351-360 2007

Inhalational Injury

Inhalational Injury

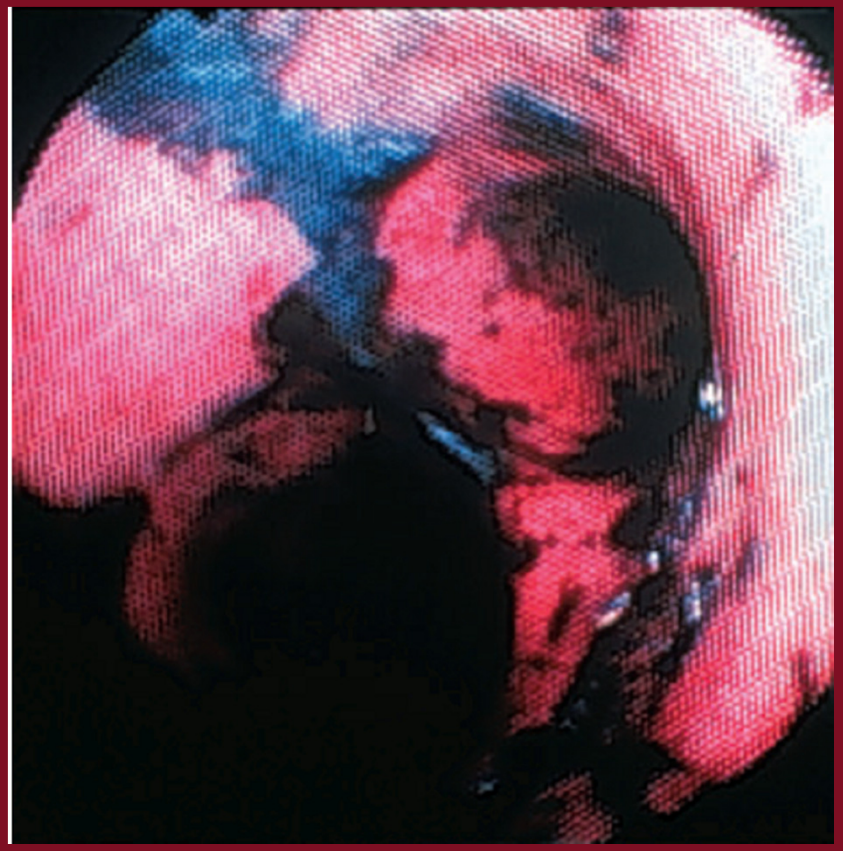
- Closed space burns
- Upper airway
  - Highly efficient heat exchanger
  - Steam can travel to distant airways
- Lower airways
  - H_2O, SO_2, NO_2 leads to H_2SO_4 and H_2NO_3
- Reduction in cross-sectional area

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)

Gonzalez R, Shanti CM. Overview of Current Pediatric Burn Care. Seminars in Pediatric Surgery 2014. doi:10.1053/j.sempedsurg.2014.11.008.

Bronchoscopy



Fidkowski CW, Fuzaylov G, Sheridan RL, Coté CJ. Inhalation burn injury in children. Pediatric Anesthesia 2009;19:147–54. doi:10.1111/j.1460-9592.2008.02884.x.

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)

Fidkowski CW, Fuzaylov G, Sheridan RL, Coté CJ. Inhalation burn injury in children. Pediatric Anesthesia 2009;19:147–54. doi:10.1111/j.1460-9592.2008.02884.x.

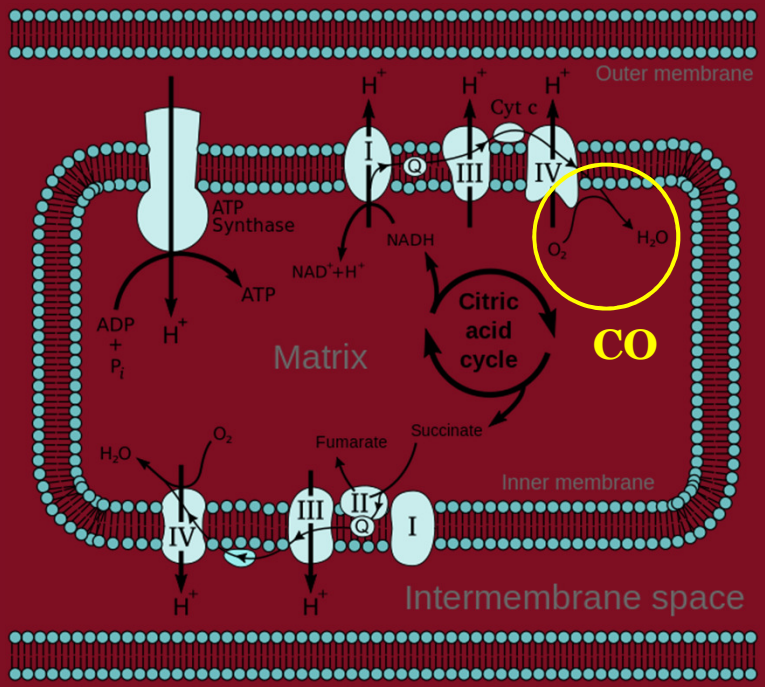
Inhalational Injury Mgmt.

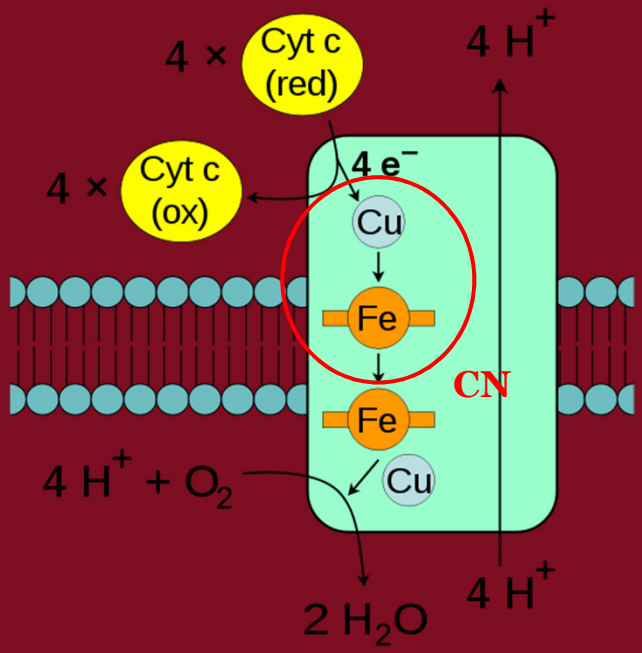
- Aggressive pulmonary toilet
- Bronchodilators
  - Albuterol q2hrs
- Inhaled heparin
- 5,000-10,000 u/3 mL normal saline q4hrs
- 20% n-Acetylcysteine
  - 3 mL q4hrs
- Hypertonic saline
- Racemic epinephrine

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