Anesthesia for Burned Patients

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Skin function

- Protects the invasion of microorganisms
- Thermal regulation
- Fluid & Electrolytes homeostasis
- Sensation ; touch, temperature, pain
- Metabolic functions ; vitamin D metabolism

Yao & Artusio, Anesthesiology, Chapter 55:Burns, 7th ed.,2012.

Causes of Burn

by

- **Radiation**

- **Electrical**

- **Thermal**

- **Chemicals**

Electrical burn

- Caused by **electrical current transmitted through the body**

- Often the only superficial sign of electrical injury is **local burn at the contact point**; hands

- Major injury lies below the surface where electrical energy is converted to thermal energy as the current encounters resistance of various tissues in its path.

- Damage to the heart makes it vulnerable to malignant arrhythmias

Thermal burn

- Caused by extremes of temperature causing **destruction of the skin layers**

- due to extreme heat or extreme cold

- cold burn injury (frostbite) has its own burn classification system , can also be associated with SIRS.

Chemical burn

- Caused by exposure to a **corrosive substance** ; strong acid, strong base, vesicant
- not require heat , until several hours to days after the exposure
- similar classification to thermal burns, but treatment specialized depending on offending agent
- consideration -> ensuring proper protection of the staff caring for the patient to limit further exposure

Anesthesia for Burned Patients

- Point of Injury Care
- Classification
- Pathophysiology
- Preoperative Preparation
- Intraoperative Consideration
- Postoperative Care
- Anesthesia for Children with Burns

Point of Injury Care

Stop the burning process

Ensure airway patency, control hemorrhage& splint fractures

Remove all constricting articles

Cover the patient

Establish intravenous access

Begin resuscitation

Primary Survey

Airway

Inhalation injury → stridor, hoarseness, cough, carbonaceous sputum, dyspnea

- may cause **airway obstruction** at any time during the first 2 days
- closely observed in ICU
- Prior to transport → prophylactic intubation
- ETT→secured with cloth ties (eg, umbilical tape)

Primary Survey

Airway

Breathing

Inhalation injury → common in pts with extensive cutaneous burns
Hx of injury in a closed space, facial burns, extremed age

- supplemental oxygen, pulse oximetry, CXR, ABG measurement

Definitive diagnosis of lower airway injury requires fiberoptic bronchoscopy

Carbon monoxide (CO) poisoning → cardiac & neurologic symptoms

- Rx: 100% Oxygen > 3 hrs or until symptoms resolve

Primary Survey

Airway

Breathing

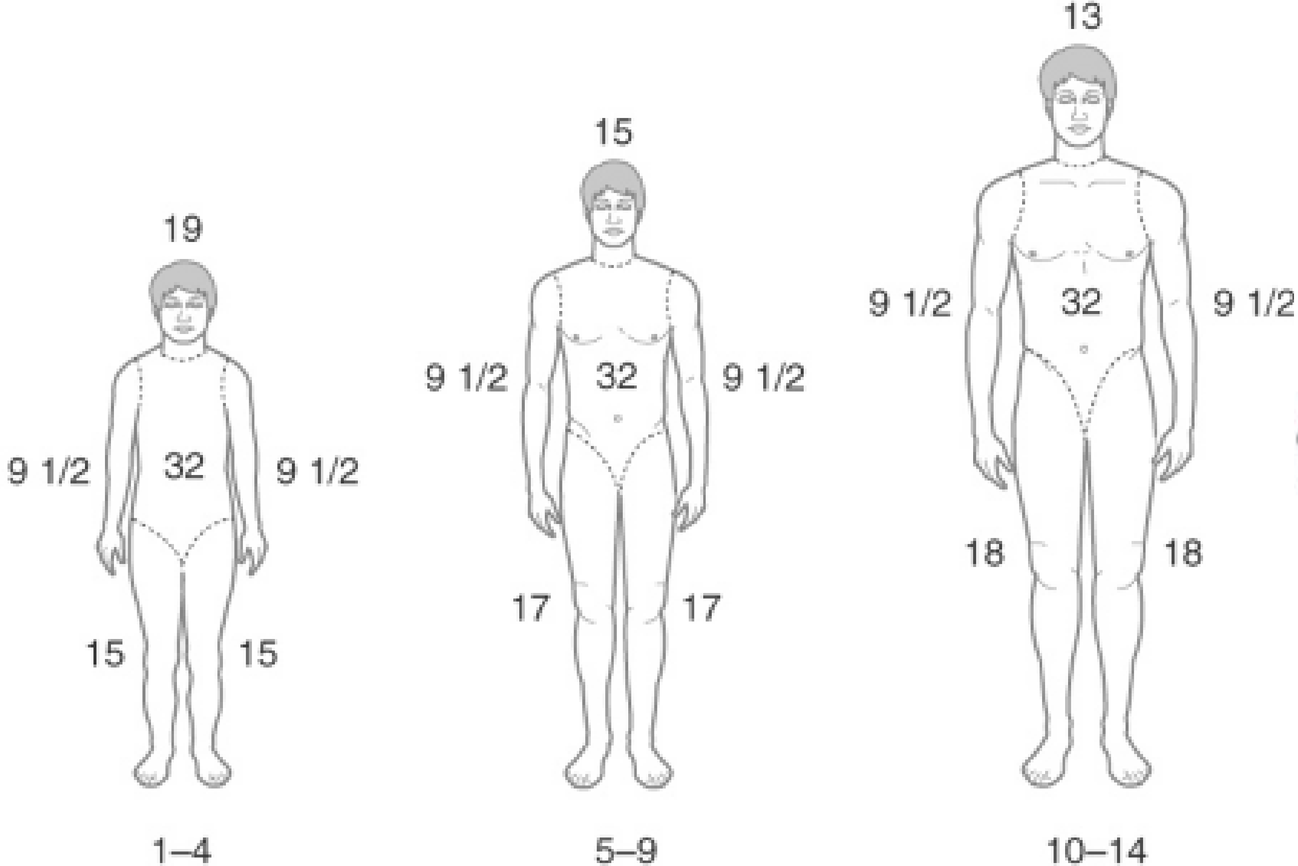
Circulation

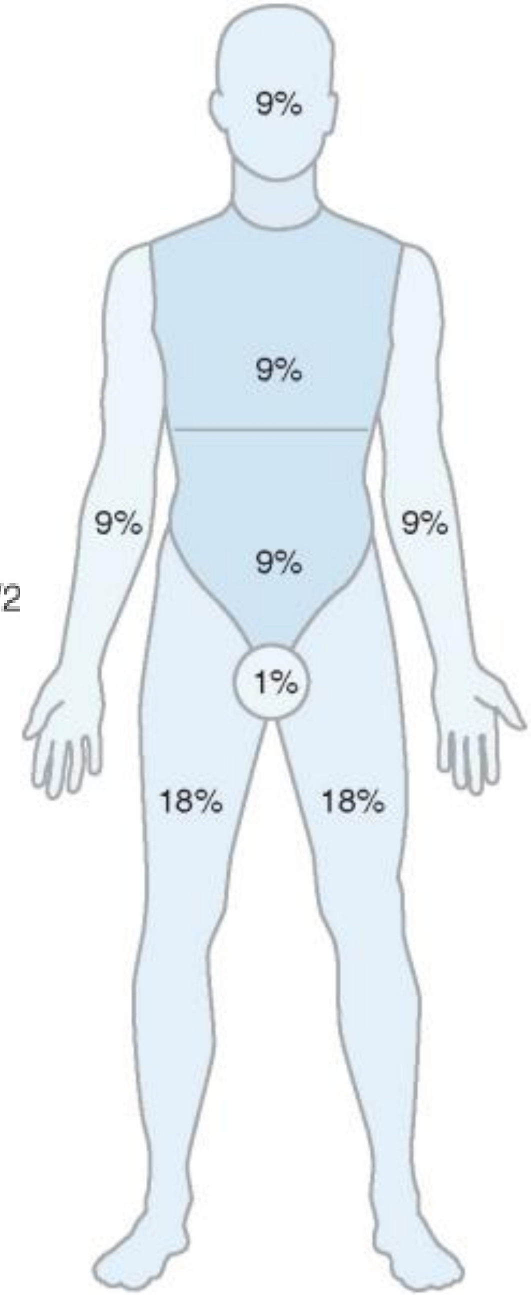
- Secure all cannulae (peripheral & central) with suture
- Arterial BP is preferred

The primary determinants of severity of burn injury are

size, **depth** and **location**

The “rule of 9s” modified for **size**





Robert S. Holzman, A Practical Approach to Pediatric Anesthesia, Chapter 37: Trauma and Casualty Management, 2008.

Burn size estimate by Lund-Browder diagram

Burn estimate and diagram
Age vs area

Initial evaluation

Cause of burn ______________________

Date of burn ______________________

Time of burn ______________________

Age ______________________

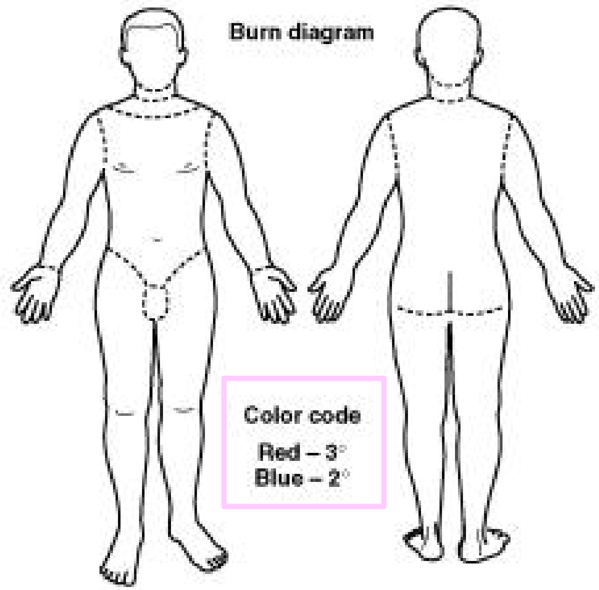
Sex ______________________

Weight ______________________

Date of admission ______________________

Signature ______________________

Date ______________________



Area	Birth 1 yr.	1–4 yrs.	5–9 yrs.	10–14 yrs.	15 yrs.	Adult	2°	3°	Total	Donor areas
Head	19	17	13	11	9	7				
Neck	2	2	2	2	2	2				
Ant. trunk	13	13	13	13	13	13				
Post. trunk	13	13	13	13	13	13				
R. buttock	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2				
L. buttock	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2				
Genitalia	1	1	1	1	1	1				
R. U. arm	4	4	4	4	4	4				
L. U. arm	4	4	4	4	4	4				
R. L. arm	3	3	3	3	3	3				
L. L. arm	3	3	3	3	3	3				
R. hand	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2				
L. hand	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2	2 1/2				
R. thigh	5 1/2	6 1/2	8	8 1/2	9	9 1/2				
L. thigh	5 1/2	6 1/2	8	8 1/2	9	9 1/2				
R. leg	5	5	5 1/2	6	6 1/2	7				
L. leg	5	5	5 1/2	6	6 1/2	7				
R. foot	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2				
L. foot	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2	3 1/2				
						Total				

New method for estimation of involved BSAs for obese

	Normal Overweight (% BSA)	Obese (% BSA)	Morbidity Obese (% BSA)
Head	5	5	5
Arms	15	15	15
Trunk	35	40	45
Legs	45	40	35

Paul G. Barash, Clinical Anesthesia, Chapter 52: Anesthesia for trauma and burn patient, 7th ed., 2013.

Classification of Burn Depth

CLASSIFICATION	BURN DEPTH	OUTCOME
Superficial		
First degree	Confined to epidermis	Heals spontaneously
Partial thickness		(typical of sunburn)
Second degree		
Superficial dermal burn	Epidermis and upper dermis	Heals spontaneously
Deep dermal burn	Epidermis and deep dermis	Requires excision and grafting for rapid return of function
Full thickness		(Painful, may heal in 7-14 days)
Third degree	Destruction of epidermis and dermis	Wound excision and grafting required Some limitation of function and scar formation
Fourth degree	Muscle, fascia, bone	Complete excision required, limited function

Electrical burn

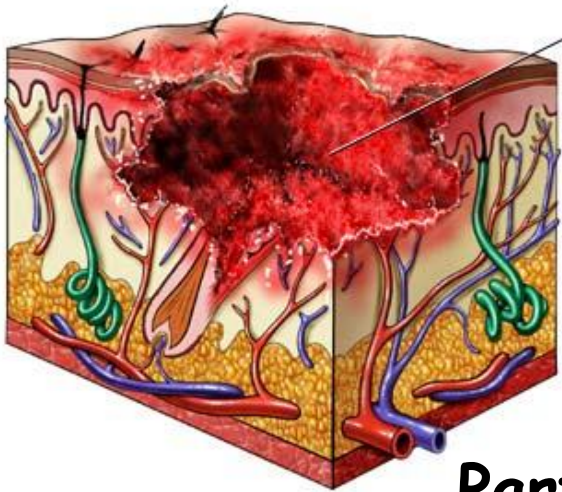
Yao & Artusio, Anesthesiology, Chapter 55: Burns, 7th ed., 2012.
Lee A. Fleisher, Anesthesia and Uncommon Diseases, Chapter 18: Burns, 5th ed. 2005.
Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Classification of Burn Depth

Depth	Level of Injury	Clinical Features	Result/Treatment
Superficial (first degree)	Epidermis	Dry, red; blanches; painful	Healing time 3–6 days, no scarring
Superficial partial thickness (superficial second degree)	Papillary dermis	Blisters; moist, red, weeping; blanches; severe pain to touch	Cleaning; topical agent; sterile dressing; healing time 7–21 days; hypertrophic scar rare; return of full function
Deep partial thickness (deep second degree)	Reticular dermis; most skin appendages destroyed	Blisters; wet or waxy dry; reduced blanching: decreased pain sensation to touch, pain present to deep pressure	Cleaning; topical agent; sterile dressing; possible surgical excision and grafting; scarring common if not surgically excised and grafted; earlier return of function with surgery
Full thickness (third degree)	Epidermis and dermis; all skin appendages destroyed	Waxy white to leathery dry and inelastic; does not blanch; absent pain sensation; pain present to deep pressure: pain present in surrounding areas of second-degree burn	Treatment as for deep partial-thickness burns plus surgical excision and grafting at earliest possible time; scarring and functional limitation more common if not grafted
Fourth degree	Involves fascia and muscle and/or bone	Pain to deep pressure, in the area of burn; increased pain in surrounding areas of second-degree burn	Healing requires surgical intervention

Superficial or First degree burn

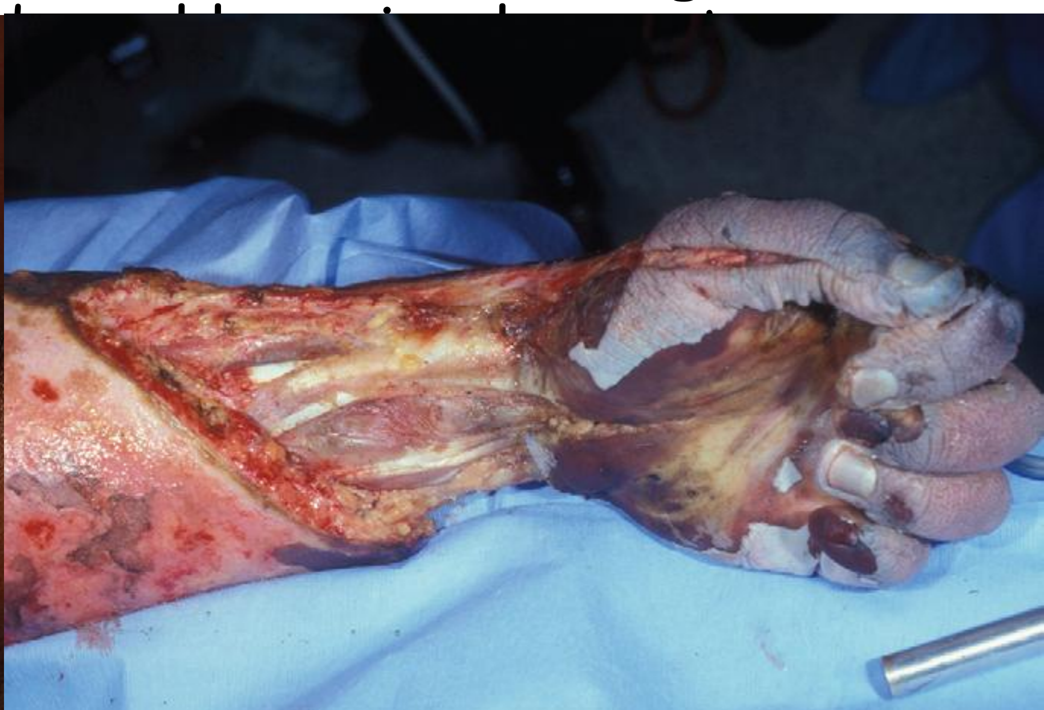
Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.



<u>Partial thickness</u> or <u>Second degree burn</u>

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

<u>Full thickness</u> or <u>Third degree burn</u>



- Muscle necrosis

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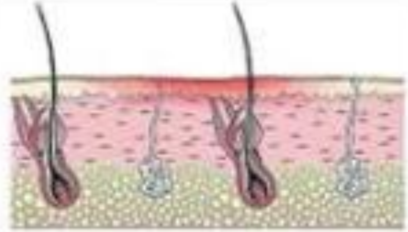
I	Reddening, swelling, pain (epidermis)		
IIa	Reddening, blistering, pain (superficial dermis)		
IIb	Pallor, blister, pain (partial dermis)		
III	Greyish white or black necrosis, analgesia (complete dermis)		
IV	Carbonization (may extend to the bones and joints)		

Burn Classification

Minor	Superficial burns < 15% TBSA
Moderate	• Superficial burns of 15-25% TBSA in adults • Superficial burns of 10-20% TBSA in children • Full-thickness burns < 10% TBSA and burns not involving the eyes, ears, face, hands, feet, or perineum
Major	• Second-degree burn ≥ 25%TBSA or ≥ 20%TBSA (Extreme age) • Third-degree burn ≥ 10% TBSA • Any size burn with accompanying inhalation injury • Electrical burns • Any complicated burn injury; •pts with serious underlying disease •pts with burns to the eyes, ears, face, hands, feet, perineum

Yao & Artusio, Anesthesiology, Chapter 55: Burns, 7th ed., 2012.
Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Major thermal burn

- 2^{nd} degree burn involving ≥ 25% of TBSA
- 2^{nd} degree burn ≥ 20% of TBSA at extremes of age
- 3^{rd} degree burn of ≥ 10% of TBSA
- Inhalation injury
- Electrical burns
- Any complicated burn injury;
  - pts with severe pre-existing medical disorders
  - pts with burns to the eyes, ears, face, hands, feet, perineum

Paul G. Barash, Clinical Anesthesia, Chapter 52: Anesthesia for trauma and burn patient, 7th ed., 2013.
Edward G. Morgan, Clinical Anesthesiology, Chapter 41:Anesthesia for the trauma patient, 4th ed., 2006.

Predicted mortality =
Age + % TBSA + Inhalation injury

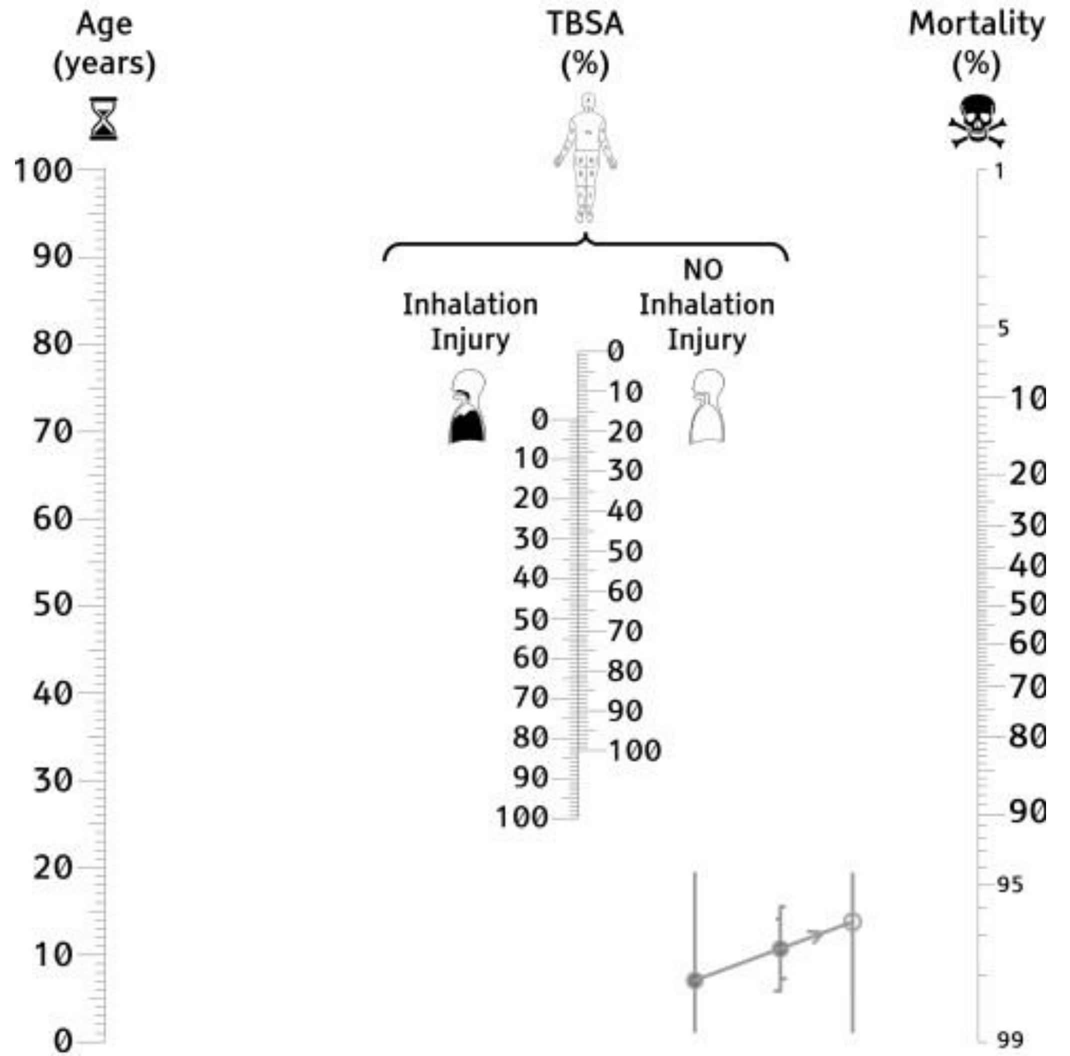
Baux score = 140 → about 50% mortality

Revised Baux Score Nomogram

Predicted Mortality (%):

Inhalation injury: $= \frac{e^{-8.8163 + (0.0775 \cdot (Age + TBSA + 17))}}{1 + e^{-8.8163 + (0.0775 \cdot (Age + TBSA + 17))}}$

NO inhalation injury: $= \frac{e^{-8.8163 + (0.0775 \cdot (Age + TBSA))}}{1 + e^{-8.8163 + (0.0775 \cdot (Age + TBSA))}}$



Instructions:
Draw a straight line connecting Age and TBSA
Use the appropriate TBSA scale for inhalation injury present/absent
Intersection of line with Mortality axis indicates predicted mortality

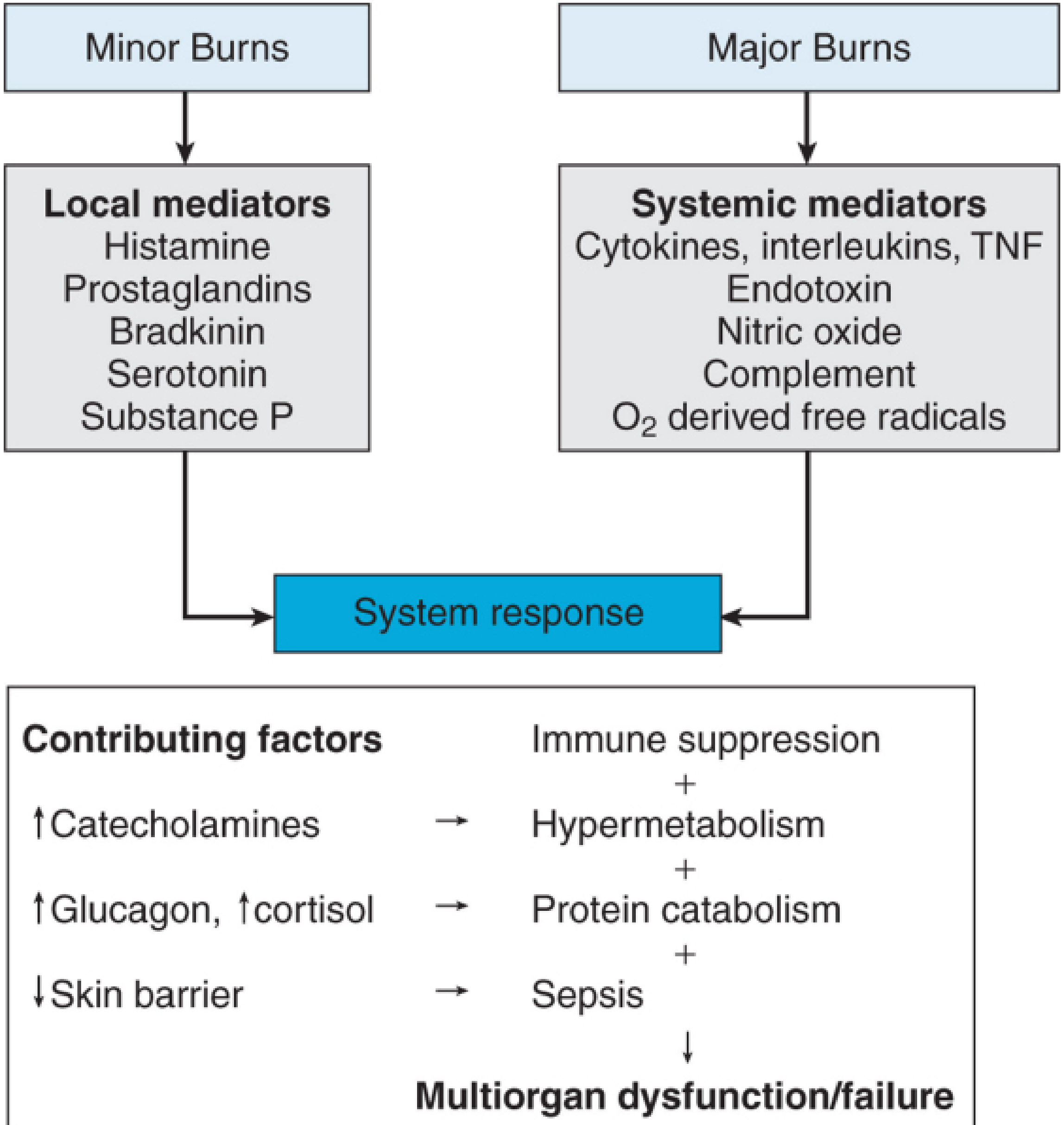
most common cause of death

- Early
  - asphyxiation from airway obstruction due to smoke inhalation
  - hypovolemic shock
- Late
  - sepsis

Pathophysiology

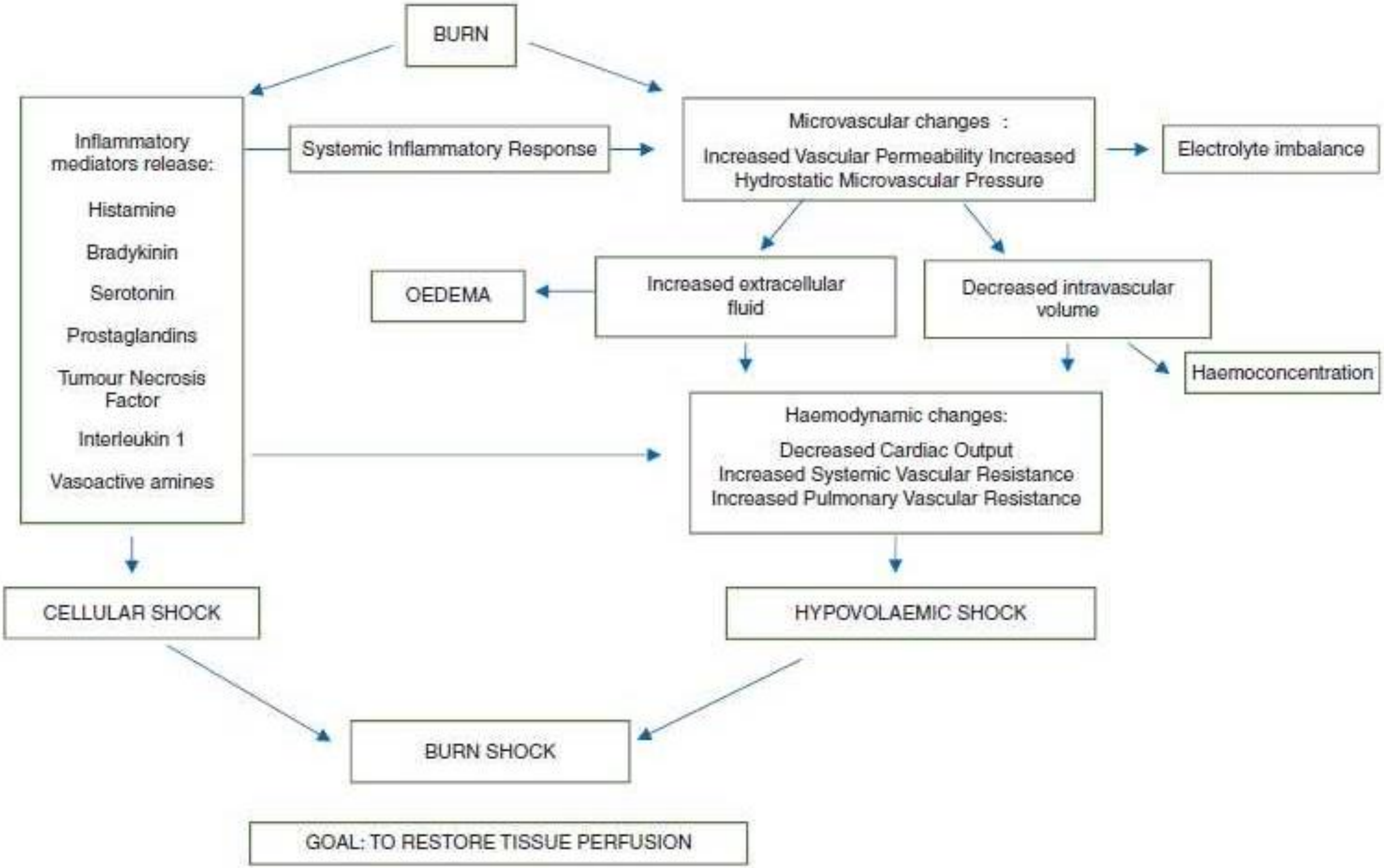
- Mediators of Inflammation
- Systemic effects of thermal injury

Pathophysiology

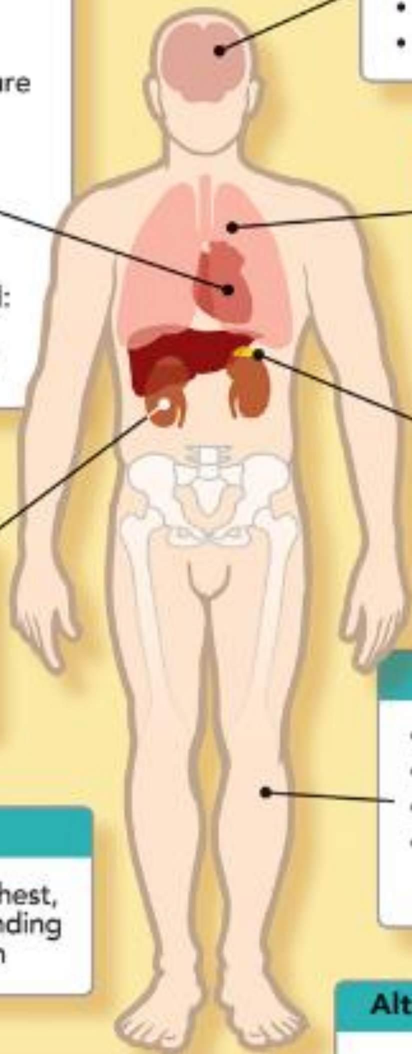


Lee A. Fleisher, Anesthesia and Uncommon Diseases, Chapter 18:Burns, 5th ed. 2005.

Burn shock pathophysiology



Pathophysiologic Changes in the Early Phase (24-48 hrs) of Burn Injury



Heart & Circulation

- Tachycardia
- ↓ Cardiac index
- ↓ Stroke volume
- Normal or low blood pressure
- ↓ SvO_2
- ↑ PVR and SVR
- ↑ Hematocrit
- CVP variable
- Metabolic acidosis
- Echocardiogram/ultrasound:
  - Small chambers
  - Decreased contractility

Brain

- Altered mental status
- ? Cerebral edema
- ↑ Pain response
- ↑ ADH

Lungs – Inhalation Injury

- Pulmonary edema
- Bronchospasm, bronchorrhea
- Acute respiratory distress syndrome

Adrenal gland

- ↑ Aldosterone
- ↑ Cortisol

Kidney-Bladder

- Myoglobinuria
- Oliguria
- Urine fractional Na^+ <1%

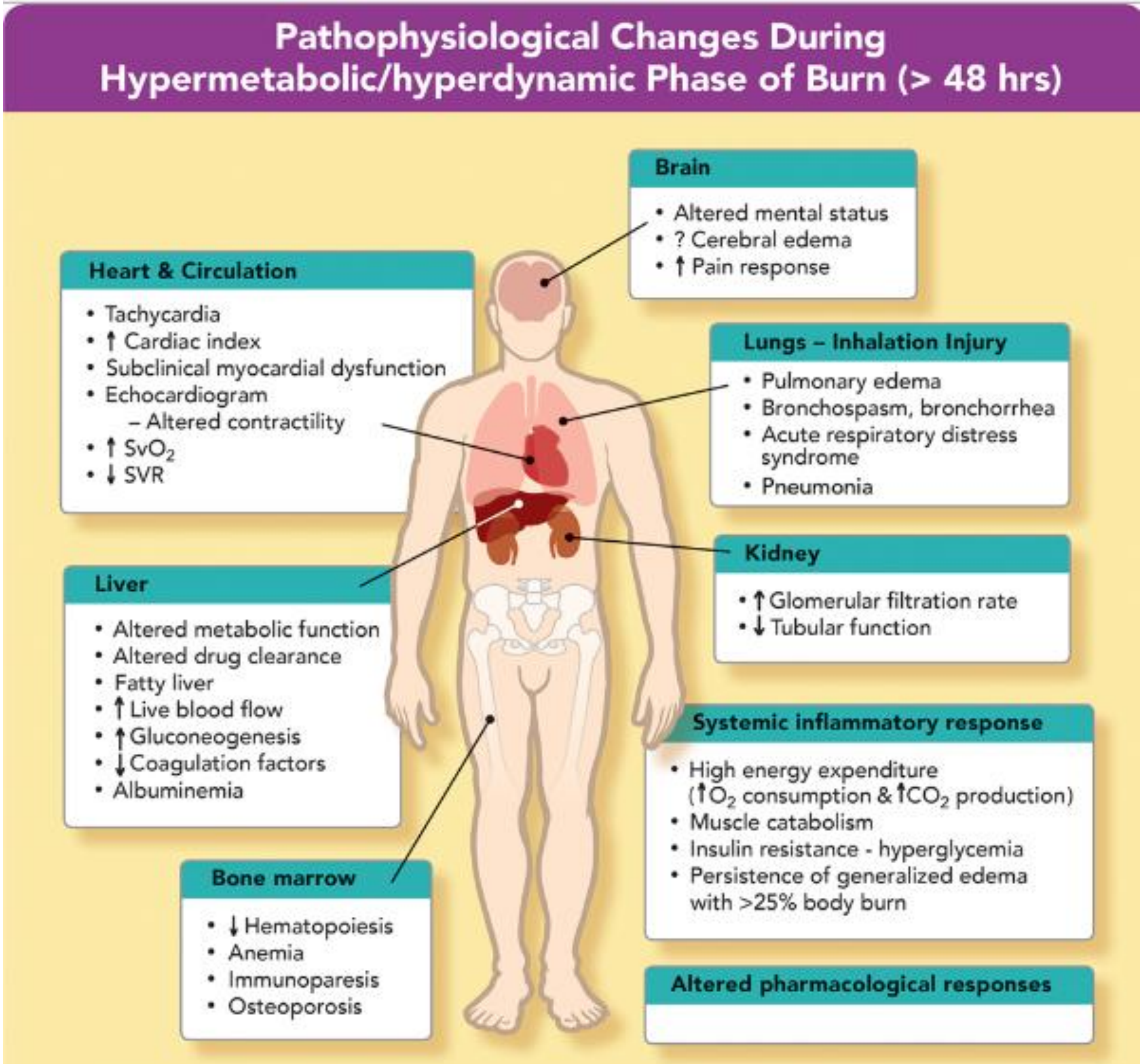
Skin

- Non-blanching burned skin
- Mottled clammy non-burned skin
- Fluid loss through burned skin
- Generalized edema in >25% body burn

Circumferential burn

- Compartment syndrome of chest, abdomen and/or limbs depending on site of circumferential burn

Altered pharmacological responses


Pathophysiological Changes During
Hypermetabolic/hyperdynamic Phase of Burn (> 48 hrs)
Brain
• Altered mental status
• ? Cerebral edema
• ↑ Pain response
Heart & Circulation
• Tachycardia
• ↑ Cardiac index
• Subclinical myocardial dysfunction
• Echocardiogram
– Altered contractility
• ↑ SvO_2
• ↓ SVR
Lungs – Inhalation Injury
• Pulmonary edema
• Bronchospasm, bronchorrhea
• Acute respiratory distress syndrome
• Pneumonia
Kidney
• ↑ Glomerular filtration rate
• ↓ Tubular function
Liver
• Altered metabolic function
• Altered drug clearance
• Fatty liver
• ↑ Live blood flow
• ↑ Gluconeogenesis
• ↓ Coagulation factors
• Albuminemia
Systemic inflammatory response
• High energy expenditure (↑O_2 consumption & ↑CO_2 production)
• Muscle catabolism
• Insulin resistance - hyperglycemia
• Persistence of generalized edema with >25% body burn
Bone marrow
• ↓ Hematopoiesis
• Anemia
• Immunoparesis
• Osteoporosis
Altered pharmacological responses

Systemic Effects of Burn Injury

System	Early	Late
Cardiovascular	↓ CO caused by decreased circulating blood volume, myocardial depression (TNFα)	↑ CO caused by sepsis or hypermetabolism Hypertension
Pulmonary	Upper- and lower-airway obstruction ↓ FRC ↓ Pulmonary compliance ↓ Chest-wall compliance	Bronchopneumonia Tracheal stenosis Restricted chest-wall expansion
Renal	↓ GFR caused by: • ↓ Circulating blood volume • Myoglobinuria • Hemoglobinuria Tubular dysfunction	↑ GFR caused by ↑ CO Tubular dysfunction
Hepatic	↓Synthetic function caused by • ↓ Circulating blood volume • Hypoxia • Hepatotoxins	Hepatitis ↑ Synthetic function caused by • Hypermetabolism • Enzyme induction • ↑ CO Dysfunction caused by sepsis or drug interaction
Hematopoietic	↓ Red cell mass, anemia Thrombocytopenia ↑ Fibrin split products Coagulopathies	Thrombocytosis Coagulopathies Transfusion reactions Transfusion-related infection
Neurologic	Encephalopathy Seizures ↑ ICP	Encephalopathy Seizures ICU disorientation
Skin	↑ Thermal, fluid, electrolyte loss	Contractures and scarring
Metabolic	↓ Ionized calcium	↑ Oxygen consumption ↑ CO_2 production ↓ Ionized calcium
Pharmacokinetics	Altered volume of distribution Altered protein binding Altered pharmacokinetics Altered pharmacodynamics	↑ Opioid/sedative tolerance Enzyme induction Altered receptor function Drug interactions

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Cardiovascular Changes

- Capillary permeability → interstitial edema
- Early

↓ CO caused by decreased circulating blood volume, myocardial depression (TNFα)

- Late → Hypermetabolic phase

↑ CO caused by sepsis or hypermetabolism
Hypertension

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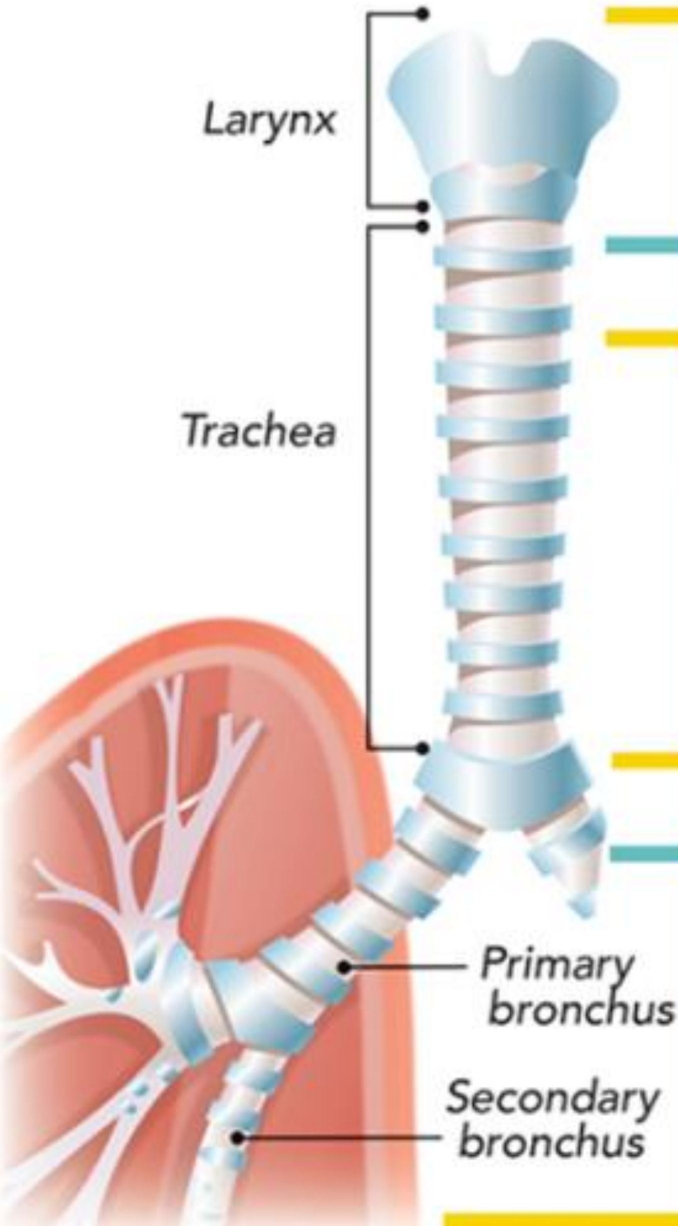
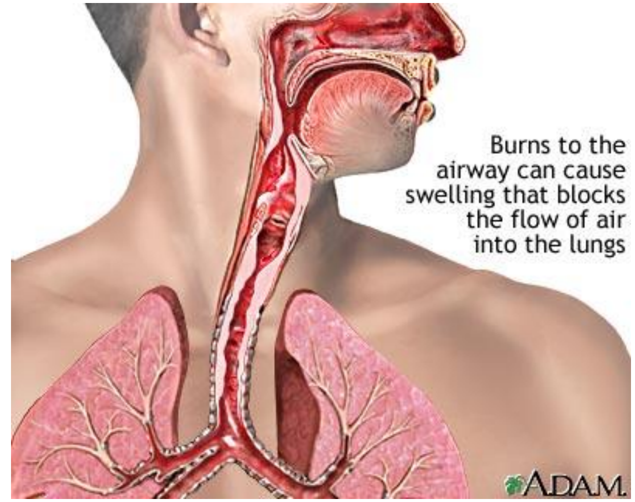
Respiratory injury from burns



Causes	Effects
Hot air Hot steam	Laryngeal obstruction Bronchospasm
Smoke Hot particles Aspiration	Mucosal slough Infection Bronchiolar plugging Atelectasis Bronchospasm
Irritant gases	Pneumonia Pulmonary edema Aveolar capillary defect

RESPIRATORY DERANGEMENTS



- Airway Injury
- Inhalation Injury
- Smoke Inhalation
- Carbon Monoxide/Cyanide Poisoning
- Additional External Factors
  - Circumferential burns of the chest may cause a mechanical restrictive effect & compromise ventilation

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Respiratory Changes

- Early

Upper- and lower-airway obstruction
↓ FRC
↓ Pulmonary compliance
↓ Chest-wall compliance

- Late

Bronchopneumonia
Tracheal stenosis
Restricted chest-wall expansion

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Pulmonary dysfunction from burn injuries

Early resuscitation phase (0-48 hours)	Upper-airway compromise Persistent bronchospasm Conducting-airway obstruction Impaired ciliary clearance Decreased lung and chest-wall compliance
Late resuscitation phase (48+ hours)	Surfactant loss Increased dead space Increased closing volume Decreased functional residual capacity Tracheobronchitis ARDS/pulmonary edema/pneumonia

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Renal Function

- Acute renal failure in burn patients ranges from 0.5-38%
- Myoglobinuria & sepsis → aggravate renal dysfunction

Renal Abnormalities

- Early

↓ GFR caused by:
- ↓ Circulating blood volume
- Myoglobinuria
- Hemoglobinuria

Tubular dysfunction

- Late

↑ GFR caused by ↑ CO
Tubular dysfunction

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Hepatic Abnormalities

- Early

↓Synthetic function caused by
- ↓ Circulating blood volume
- Hypoxia
- Hepatotoxins

- Late

Hepatitis
↑ Synthetic function caused by
- Hypermetabolism
- Enzyme induction
- ↑ CO

Dysfunction caused by sepsis or drug interaction

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Hematopoietic Abnormalities

- Early

↓ Red cell mass, anemia
Thrombocytopenia
↑ Fibrin split products
Coagulopathies

- Late

Thrombocytosis
Coagulopathies
Transfusion reactions
Transfusion-related infection

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Neurologic Abnormalities

- Early

Encephalopathy
Seizures
↑ ICP

- Late

Encephalopathy
Seizures
ICU disorientation

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Skin Abnormalities

- Early ↑ Thermal, fluid, electrolyte loss

- Late Contractures and scarring

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Metabolic Abnormalities

- Early
  - ↓ Ionized calcium
- Late
  - ↑ Oxygen consumption
  - ↑ CO_2 production
  - ↓ Ionized calcium

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Metabolic Changes

- 10-fold increase in catecholamines → hypermetabolic response
- Resetting of core temperature to higher levels
- Loss of barrier function of skin & blunting of immune response → increased susceptibility to infection

Limiting catecholamine secretion by;

- Adequate pain control
- Alleviation of anxiety
- Maintenance of a thermoneutral environment
- Treatment of infection

Pharmacokinetic Abnormalities

- Early

Altered volume of distribution
Altered protein binding
Altered pharmacokinetics
Altered pharmacodynamics

- Late

↑ Opioid/sedative tolerance
Enzyme induction
Altered receptor function
Drug interactions

Thomas Romanelli: Smith's Anesthesia for Infants and Children, Chapter 31: Anesthesia for Burn Injuries, 8th ed. 2011.

Pharmacologic Changes

- ↓ serum albumin leads to
  - increased free fraction of acidic drugs ; thiopental , antiepileptics or diazepam
- ↑ α-acid glycoprotein results in
  - decreased free fraction of basic drugs

  (pKa > 8) ; lidocaine , tricyclic antidepressants , NDMR or propranolol
- NMDR require doses 2.5-5 times > nonburned pts → serum half-life is unchanged

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Inhalation Injury

- Upper Airway Injury
  - Unless steam is involved, heat injury to airway is **supraglottic** → swelling of posterior pharynx & supraglottic → upper airway obstruction 12-48 hrs
- Lower Airway Injury (Smoke Inhalation Injury); carbon monoxide, cyanide, hydrochloric acid, aldehyde gases, oxidants
  - 24 - 72 hrs after injury → dyspnea, rales, rhonchi, wheezing
  - damage to mucociliary function, bronchial vessel permeability, bronchospasm, alveolar destruction, pulmonary edema → pulmonary infection, barotrauma, atelectasis, pulmonary shunting

Upper airway edema

Signs/Symptoms

- High level of suspicion
- Hoarseness
- Facial burns
- Soot in nasal or oral secretions
- Persistent cough
- Wheezing

Upper airway edema

Treatment

- Early intubation before edema makes it impossible
- Humidified O_2 → clear secretion
- Bronchodilators → bronchospasm
- Elevate HOB 20-30 degree → decrease edema

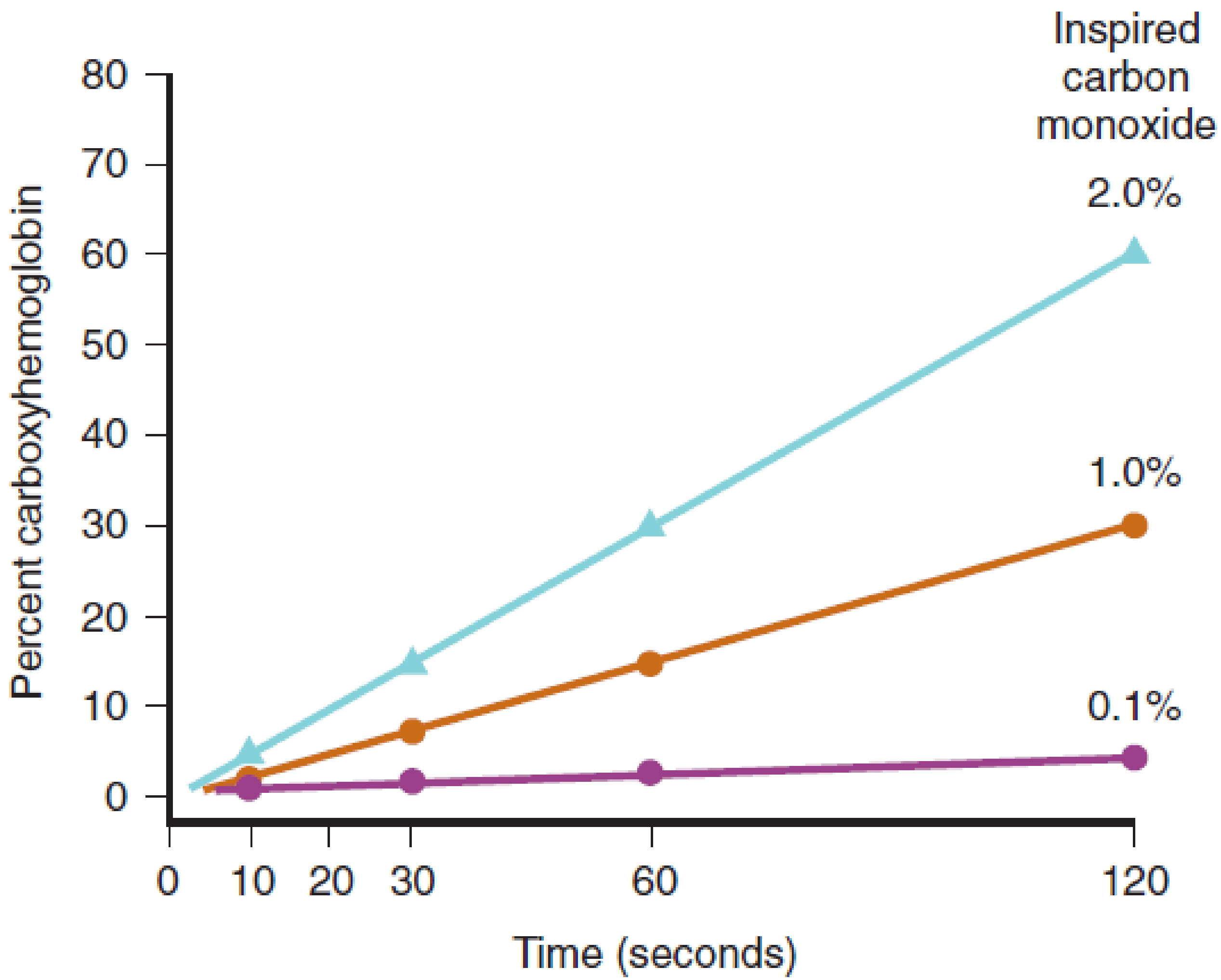
HOB = Head of bed

Carbon Monoxide Toxicity

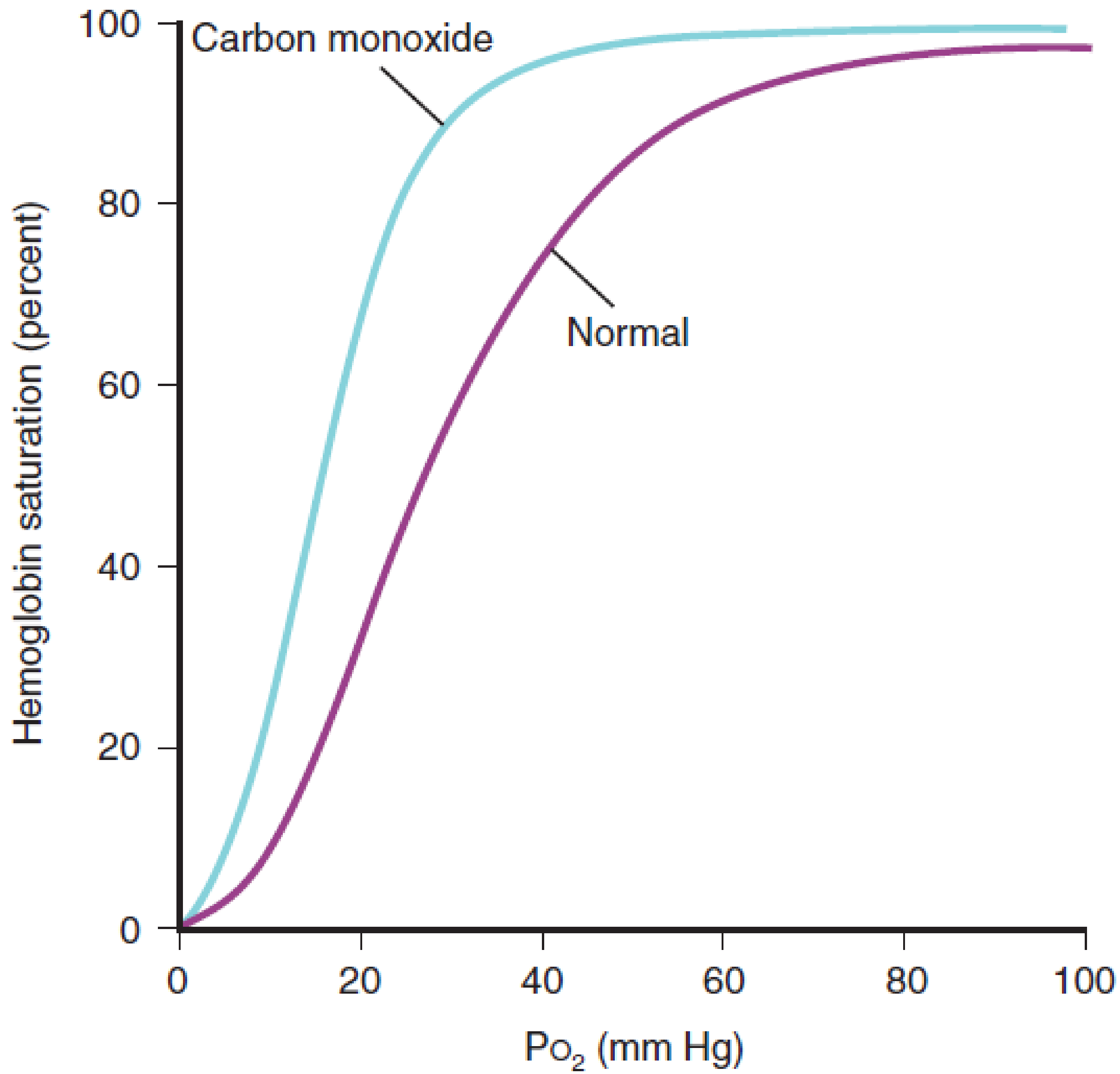
- Normal COHb
  - < 1.5% in nonsmokers
  - < 10% in smokers
- CO high affinity for Hb (250 times > oxygen)
- Rx: 100% Oxygen reduces the half-life of COHb from 2.5 hrs to 40 mins & facilitates the elimination of CO

Edward G. Morgan, Clinical Anesthesiology, Chapter 41:Anesthesia for the trauma patient, 4th ed., 2006.

CARBOXYHEMOGLOBIN
VS
INSPIRED CARBON MONOXIDE

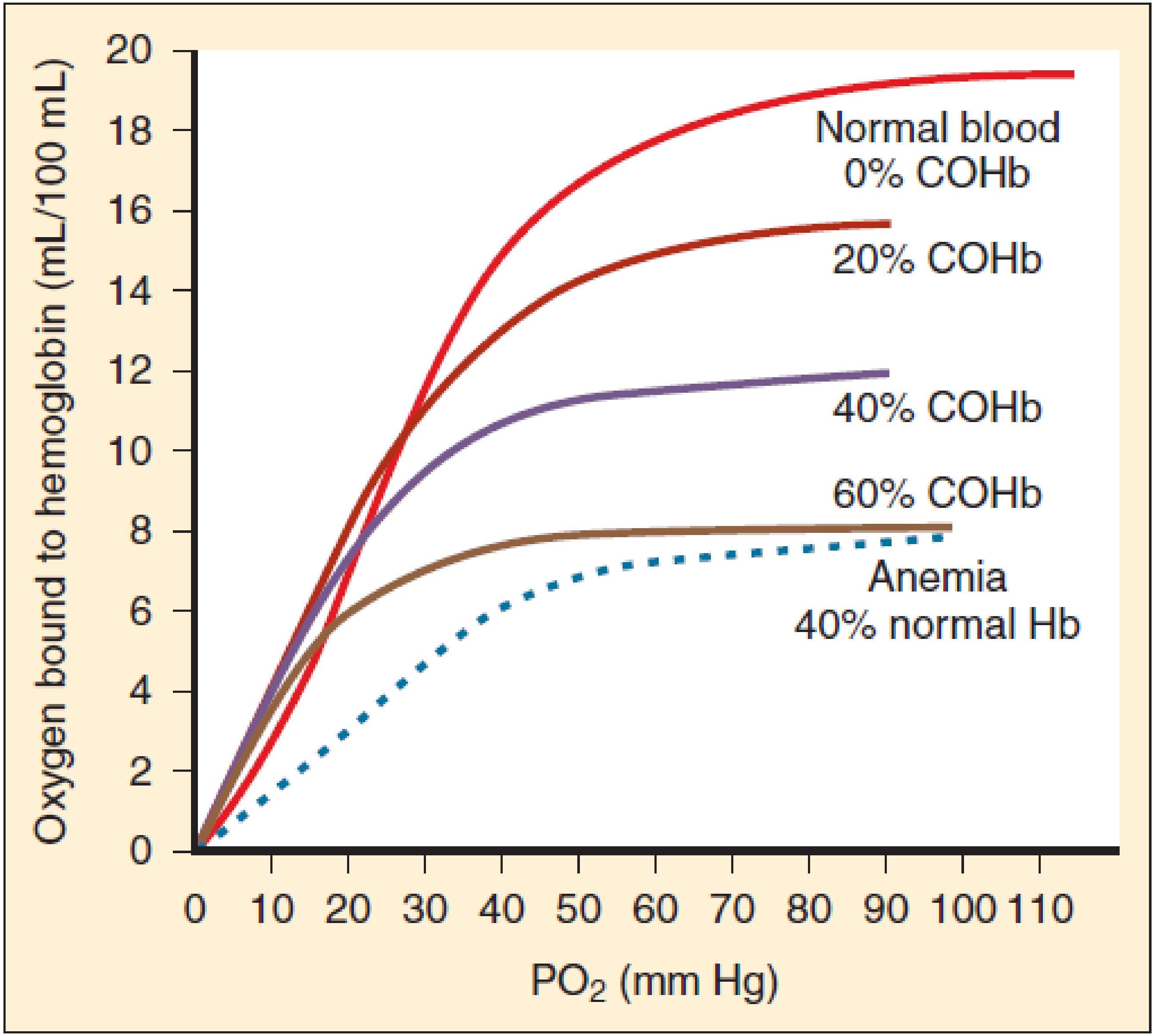


Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.



Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Symptoms of Carbon Monoxide Toxicity



Paul G. Barash, Clinical Anesthesia, Chapter 36: Anesthesia for trauma and burn patient, 6th ed., 2009.

Symptoms of Carbon Monoxide Toxicity

Blood COHb Level (%)	Symptoms
<15–20	Headache, dizziness, and occasional confusion
20–40	Nausea, vomiting, disorientation, and visual impairment
40–60	Agitation, combativeness, hallucinations, coma, and shock
>60	Death

Paul G. Barash, Clinical Anesthesia, Chapter 52: Anesthesia for trauma and burn patient, 7th ed., 2013.

Cyanide toxicity

- Normal blood cyanide level is < 0.2 mg/mL
- Cyanide → tissue hypoxia by uncoupling oxidative phosphorylation in mitochondria
- Signs & Symptoms

cyanide level

- 50 ppm → Headache, dizziness, tachycardia & tachypnea
- >100 ppm → seizures or respiratory failure

suspected in presence of

- persistent high anion gap metabolic acidosis
- high lactate levels that fail to respond to O_2 administration

Edward G. Morgan, Clinical Anesthesiology, Chapter 41:Anesthesia for the trauma patient, 4th ed., 2006.

Cyanide toxicity

- Rx:
  - Oxygen therapy or Intubation
  - IV fluid load for hypotension
  - $NaHCO_3$ for acidosis
  - Diazepam for convulsion
  - Antidote ;
    - 3% Sodium nitrite 10 ml
    - 25% Sodium thiosulfate 50 ml
    - Hydroxocobalamin, dicobalt edetate

Edward G. Morgan, Clinical Anesthesiology, Chapter 41:Anesthesia for the trauma patient, 4th ed., 2006.

Signs & Symptoms for Cyanide toxicity

Level (mg/ml)	Symptomatology
<0.03	Normal
0.5-1.0	Hyperventilation, tachycardia
1.0-3.0	Decreased mental state, may be fatal
>3.0	Fatal unless treated

Systems	Manifestations
Odor	Bitter almond breath (not always present)
Skin	Cherry red color or cyanosis
CNS disturbance	Headache, agitation, disorientation, lethargy, seizures, coma, cerebral death
Cardiovascular instability	Changes in oxygenation Tachycardia –> apnea, venous hyperoxemia: red venous blood, increased mixed venous O2 content (SvO2), decreased O2 consumption (vO2), narrow arteriovenous O2 difference (AvO2 diff)
Metabolic acidosis	pH-elevated blood lactate and/or elevated lactate: pyruvate ratio

Preoperative Preparation

- Things to Prepare for Burn Excision & Grafting

Difficult airway cart, umbilical tape, dental floss, wire for suturing tube
Operating room warmed to 28° to 32°C, fluid warmer, radiant heat warmer
Availability of blood products
Adequate intravenous access; consider invasive monitorings

Major Preoperative Concerns for Burn Patients

- Age of patient
- Extent of burn injury (total body surface area, depth, and location)
- Mechanism of injury
- Presence of inhalational injury
- Airway patency
- Adequacy of resuscitation
- Presence of organ dysfunction
- Elapsed time from injury
- Associated injuries
- Presence of infection
- Coexisting diseases
- Surgical plan

David E. Longnecker, Anesthesiology, Chapter 71:Anesthetic Management of the Burned Patient, 2008.

Topical Antimicrobial Agents and Their Toxicities

decreases serum sodium, chloride, potassium

inhibits carbonic anhydrase → hyperchloremic acidosis

	Effectiveness	Side Effects	Ease of Use	Pain
Silver nitrate ($AgNO_3$) 0.5% aqueous solution	Inhibits cell wall growth Penetrates 2–4 mm into wound	Leeches plasma electrolytes	dressings Change daily and soak q2h to keep damp Stains tissue and environment black	Stings briefly
Mafenide acetate (famylon aqueous solution)	Effective for resistant organisms (i.e., *Pseudomonas*)	of HCO_3 wasting Sensitivity rash	Change daily and soak q6h to keep damp	briefly
Silver sulfadiazine (Silvadene 1% cream)	Broad spectrum Chemical debriding agent	Dose-related neutropenia Contains sulfur Sensitivity rash	Change daily To prevent buildup, remove residue with each dressing change	Stings briefly
Bacitracin ointment	Broad spectrum antibiotic ointment for partial-thickness wounds	Hypoallergenic (does not contain sulfur compounds)	Daily dressing change Apply and cover with dressing	No pain

David E. Longnecker, Anesthesiology, Chapter 71:Anesthetic Management of the Burned Patient, 2008.

Indication for early endotracheal intubation

- Pts with **severe head & neck burns**
- Pts with **steam burns** of the face
- Pts **burned in a closed space** who have inhaled smoke or other noxious products of incomplete combustion
- **Hypoxia** not correctable with a face mask
- Presence of **copious secretions**

Robert S. Holzman, A Practical Approach to Pediatric Anesthesia, Chapter 37: Trauma and Casualty Management, 2008.

Guidelines for initial fluid resuscitation

Adults and Children >20 kg

Parkland formula[a]

4.0 mL crystalloid/kg/% burn/first 24 hr

Modified Brooke Formula[a]

2.0 mL lactated Ringer's/kg per % burn per first 24 hr

Children <20 kg

Crystalloid 2–3 mL/kg per % burn per 24 hr[a]

Crystalloid with 5% dextrose at maintenance rate

100 mL/kg for the first 10 kg and 50 mL/kg for the next 10 kg for 24 hr

Clinical End Points of Burn Resuscitation

Urine output: 0.5–1 mL

Pulse: 80–140 per min (age dependent)

Systolic BP: 60 mm Hg (infants); children 70–90 plus 2x age in years mm Hg; adults MAP > 60 mm Hg

Base deficit: <2

Paul G. Barash, Clinical Anesthesia, Chapter 52: Anesthesia for trauma and burn patient, 7th ed., 2013.

Formulae for Fluid Resuscitation after Burn Injury

Parkland	LR	4 ml/kg/%TBSA Burn
Brooke	LR	1.5 ml/kg/%TBSA burn
	Colloid	0.5 ml/kg/%TBSA burn

For example for *g*., For 70-kg person with 60% burn:

Parkland formula: 4 × 70 × 60 = 16,800 ml of LR/24 h;

Brooke formula: 1.5 × 70 × 60 = 6,300 ml of LR/24 h;

0.5 × 70 × 60 = 2,100 ml colloid/24 h.

For either formula, half of total volume is administered over the first 8 h. Infusion rates should always be adjusted up or down based on physiological responses.

LR = lactated Ringer's; TBSA = total body surface area.

Estimation of Fluid Resuscitation Needs

- Estimate crystalloid needs → first 24 hrs

Total Volume = 2 mL x % burn x BW(kg)

- Half of total volume → first 8 hrs
  and half of this → second 16 hrs
- Children (< 30kg) have a greater surface-to-weight ratio
→ formula 3 cc/kg/%burn

Parkland formula:
4 cc of RLS / kg / %TBSA / 24 hrs

Emergency war surgery, Chapter 28: Burns, 3rd ed., 2004.

Indicators of Adequate Circulating Volume and/or Resuscitation

Urine output	0.5–1.0 $ml \cdot kg^{-1} \cdot h^{-1}$
Blood pressure*	Within normal range for age
Heart rate†	Variable
Central venous pressure‡	3–8 mmHg
Fractional excretion of Na+ (FeNa)§	<1% (indicates hypovolemia)
BUN/Cr ratio‖	≥20 (indicates hypovolemia)
Echocardiogram/ultrasound	Normal stroke volume and ejection fraction
Base deficit	<5

$$\S FeNa = 100 \times \frac{Sodium - urinary \times creatinine - plasma}{Sodium - plasma \times creatinine - urinary}$$

Burn resuscitation endpoints

- **Arousable** & **Comfortable**
- **Warm extremities**
- **SBP** in
  - Infant 60 mmHg
  - Older children 70-90 + (2 x *Age*) mmHg
- **MAP** > 65 mmHg or within 20% Baseline
- **HR** 80-150 bpm (*Age*-dependent)
- **Urine output** 0.5 ml/kg/h
- **Lactate levels** < 2 mmol/l

Essential clinical anesthesia review : keywords, questions and answers for the boards, Chapter 65: Burn management, 2015.

Resuscitation Management, First 24 Hrs

- Urine output = 30-50 mL/hr or 1 mL/kg/hr in children

By adjust LR infusion rate about ±25%

- Avoid over-resuscitation → edema-related complications ; compartment syndromes, pulmonary edema
- Other indices of adequate resuscitation
  - decreasing base deficit
  - moderate tachycardia (Normal HR in Burn = 100-130BPM)
  - acceptable mental status
- Glycosuria is common following severe thermal injury → Rx hyperglycemia with IV insulin

Emergency war surgery, Chapter 28: Burns, 3rd ed., 2004.

Benefit of LRS vs NSS for resuscitation

LRS → lower Na & higher pH

- Closer to physiologic levels
- Metabolized lactate has a buffering effect on metabolic acidosis associated with burns

Resuscitation Management, Second 24 Hrs

5%Albumin volume = (* mL) x %TBSA burned x BW (kg)

% TBSA burn	30–49	50–69	70+
* mL	0.3	0.4	0.5

- Burns < 30% TBSA do not require colloid infusion
- FFP or synthetic colloid can be used at the same dose
- Monitoring urine output
- At 24 hrs, start D5W at half the last hourly rate of LR
- Follow serum sodium closely → **beware of hypo-hypernatremia**
- Resuscitation is usually complete by the 48 hrs postburn
- Continued evaporative water loss replacement is needed

Emergency war surgery, Chapter 28: Burns, 3rd ed., 2004.

- Treatment with 5 % albumin from Day 0 - 14 does not decrease the burden of MODS in adult.

Cooper, et al., Transfusion. 46(1):80-89, January 2006.

- The incidence of venous thromboembolism(VTE) in thermally injured pts = 0.6%.
- VTE incidence increased to 1.2% when pts required ICU admission or >10%TBSA burns.
- Pts with 40 - 59% TBSA burns were at highest risk for VTE (2.4%)

Pannucci, et al., Journal of Burn Care & Research. Publish Ahead of Print, POST COPYEDIT, 1 December 2010.

Parkland formula

Crystalloid Regimens		
Parkland	Lactated Ringer's	4 mL/kg/% burn
Modified Brooke	Lactated Ringer's	2 mL/kg/% burn
Colloid regimens		
Evans	Normal saline	1 mL/kg/% burn
	Colloid	1 mL/kg/% burn
	5% Dextrose	2,000 mL/24 hr
Brooke	Lactated Ringer's	1.5 mL/kg/% burn
	Colloid	0.5 mL/kg/% burn
	5% Dextrose	2,000 mL/24 hr

Yao & Artusio, Anesthesiology, Chapter 55: Burns, 7th ed., 2012.

Major Preoperative Concerns for Burn Patients

Age of patient	Elapsed time from injury
Extent of burn injury (total body surface area, depth, and location)	Associated injuries
Mechanism of injury	Presence of infection
Inhalational injury and/or lung dysfunction	Coexisting diseases
Airway patency	Immune dysfunction
Hematologic issues	Altered drug responses
Adequacy of resuscitation	Magnitude of surgical plan
Presence of organ dysfunction	Difficult vascular access
Gastric stasis	Altered mental states

Guidelines to Anesthetic Management

- Psychological support
- Nutrition
- Adequate sedation and pain control
- Correction of intravascular volume
- Minimize heat loss
- Adequate monitoring
- Specific anesthetic equipment

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Monitoring

Standard monitoring

- ECG
- Pulse oximeter
- NIBP

Burns of ≥ 20%TBSA

- Two intravenous catheters (IV)
- Central venous catheter
- Foley catheter
- Core thermometer
- Nasogastric (NG) tube

Intraoperative Consideration

- After the first 24 hrs, **succinylcholine** must be avoided for as long as 1 year.

(Large increases in serum K occur when burn size > 10% of TBSA)

Paul G. Barash, Clinical Anesthesia, Chapter 36: Anesthesia for trauma and burn patient, 6th ed., 2009.

- **Succinyl choline** → contraindicated in burn pts after the first 24 hr - 2 yrs

David E. Longnecker, Anesthesiology, Chapter 71:Anesthetic Management of the Burned Patient, 2008.

Yao & Artusio,Anesthesiology, Chapter 55:Burns, 7th ed.,2012.

Intraoperative Consideration

- Require higher than normal doses of **NDMR**
  →Resistance to NDMR develops in pts **>30% burns** starting about 1 week after the burn injury & peaking in 5-6 weeks

Paul G. Barash, Clinical Anesthesia, Chapter 36: Anesthesia for trauma and burn patient, 6th ed., 2009.

- increased **narcotic** requirements

David E. Longnecker, Anesthesiology, Chapter 71:Anesthetic Management of the Burned Patient, 2008.

Intraoperative Consideration

Hypothermia is a risk in the operating room.

- maintain body temperature by
  - Room temperature maintained at 28◦C to 32◦C
  - inspired gases should be humidified
  - warming blankets
  - radiant warmers
  - blood/fluid warmers
  - wrapping head & extremities with plastic or thermal insulation

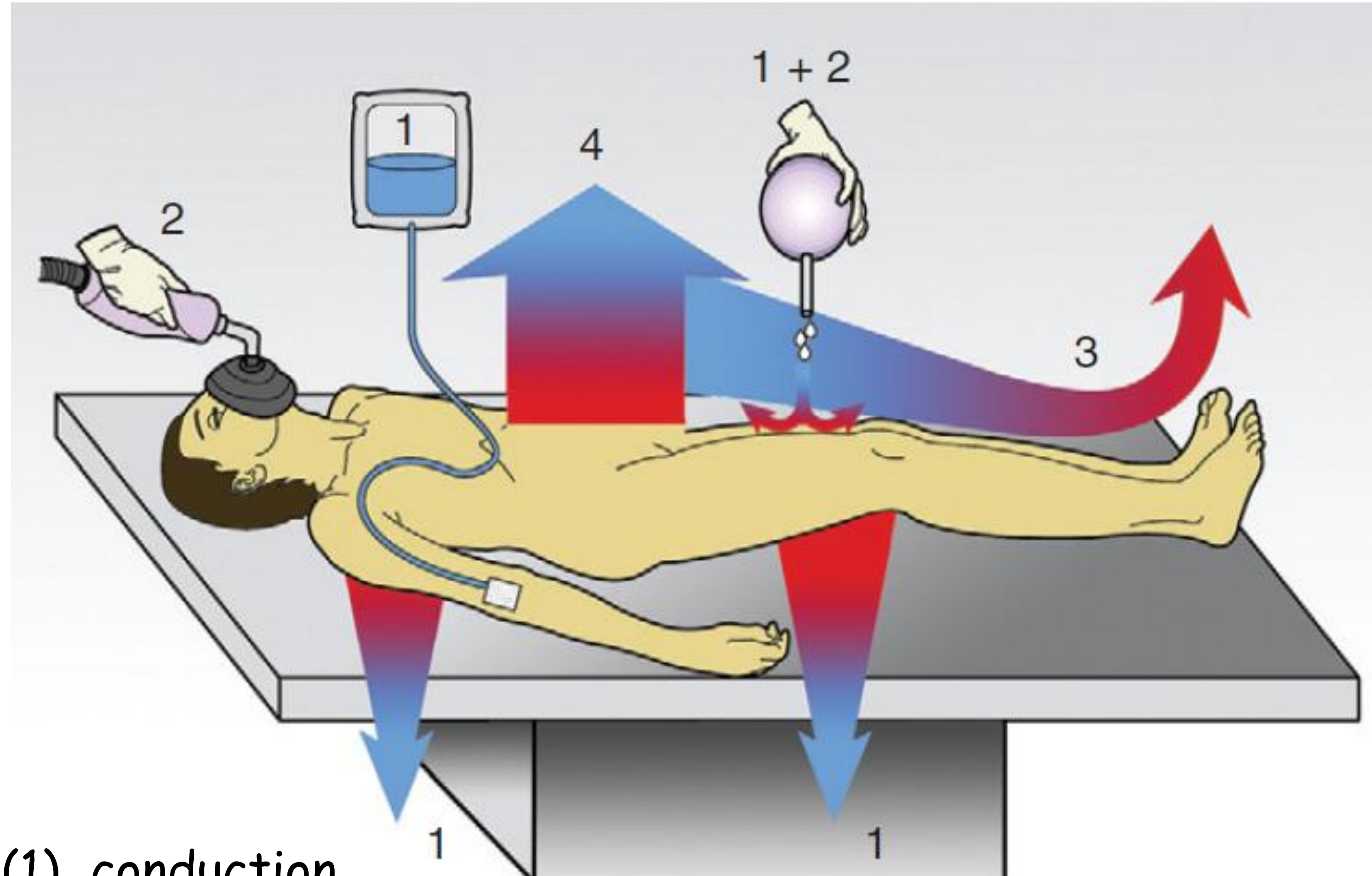
Normothermia for a burned patient is ~38.5◦C

Yao & Artusio, Anesthesiology, Chapter 55: Burns, 7th ed., 2012.

David E. Longnecker, Anesthesiology, Chapter 71: Anesthetic Management of the Burned Patient, 2008.

Paul G. Barash, Clinical Anesthesia, Chapter 36: Anesthesia for trauma and burn patient, 6th ed., 2009.

4 Mechanisms of heat loss

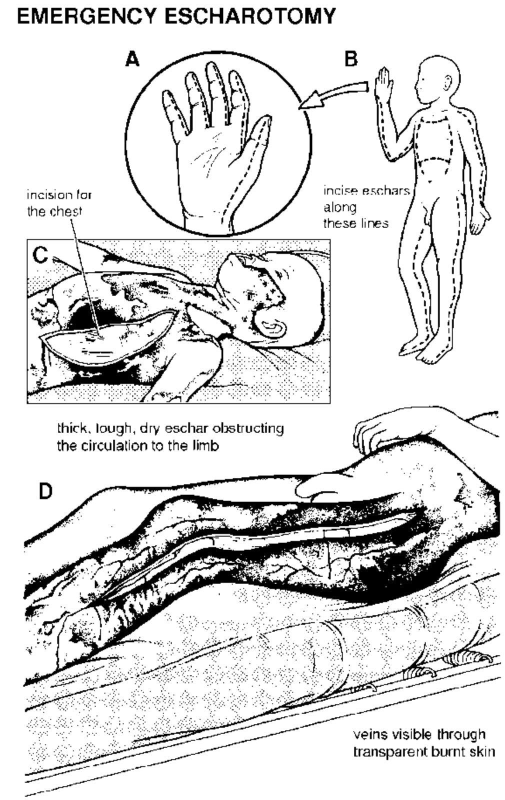


(1) conduction
(2) evaporation
(3) convection
(4) radiation

Smith's Anesthesia for Infants and Children, 8th ed., 2011.

Intraoperative Consideration

- Hypermetabolic state → increased oxygen, ventilation, & nutrition
- Extensive escharotomies
  - massive transfusions
  - temperature control
  - management of fluid, electrolyte, coagulation abnormalities



- The extent of excision is limited =20%
- For serial wound debridement;
  - ketamine in intermittent doses
  - neuraxial or peripheral nerve blocks via indwelling catheter
  - sedation with opioids and IV agents

Paul G. Barash, Clinical Anesthesia, Chapter 36: Anesthesia for trauma and burn patient, 6th ed., 2009.

Special Considerations

- Pharmacologic Responses
- Methemoglobinemia
- Endotracheal Tube Size
- Airway Control
- Hyperalimentation
- Awakening

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Pharmacologic Responses

- Pt. with burn injuries require **larger** than normal doses of all medications;
  - Antibiotics
  - Muscle relaxants
  - Opioids
  - Benzodiazepines
- Drug interactions;
  - H_2-receptor antagonists → inhibit the clearance of many other medications

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Methemoglobinemia

- source of intraop. cyanosis & hypoxemia
- silver nitrate dressings

gram-negative bacteria → reducing nitrates to nitrites → creates nitrites diffuse into the bloodstream → converting hemoglobin into methemoglobin

- visible cyanosis = 5 g/dL of deoxyhemoglobin
- Treatment
  - Removing toxic agent by administration of methylene blue (2 mg/kg)
  - High inspired oxygen concentrations

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Endotracheal Tube Size

- **cuffed ETT** should usually be **used & record** maintained of the size of ETT, volume of air inflated into the cuff , pressure at which leakage occurs around the ETTfor each anesthetic procedure

- use of **smaller** diameter ETT as weeks go by,

- development of a subglottic lesion (stenosis, granuloma, polyps), which should be investigated with bronchoscopy

- When nitrous oxide is used, the intraoperative cuff pressure should be checked to avoid excessive pressure

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Airway Control

- difficult airway challenge to the anesthesiologist due to
  - temporomandibular joint limitation
  - macroglossia from thermal injury
  - neck contractures
  - direct thermal/inhalational injuries to the glottis & respiratory tree

- Fiberoptic intubations on spontaneously breathing children under Dexmedetomidine

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Hyperalimentation

- Hyperalimentation fluids →continued intraoperatively (Reduce rate to ½ - 2/3)
- Administered with a constant-infusion pump
- Monitoring of blood glucose level
- Compatibility of hyperalimentation solutions with drugs or blood

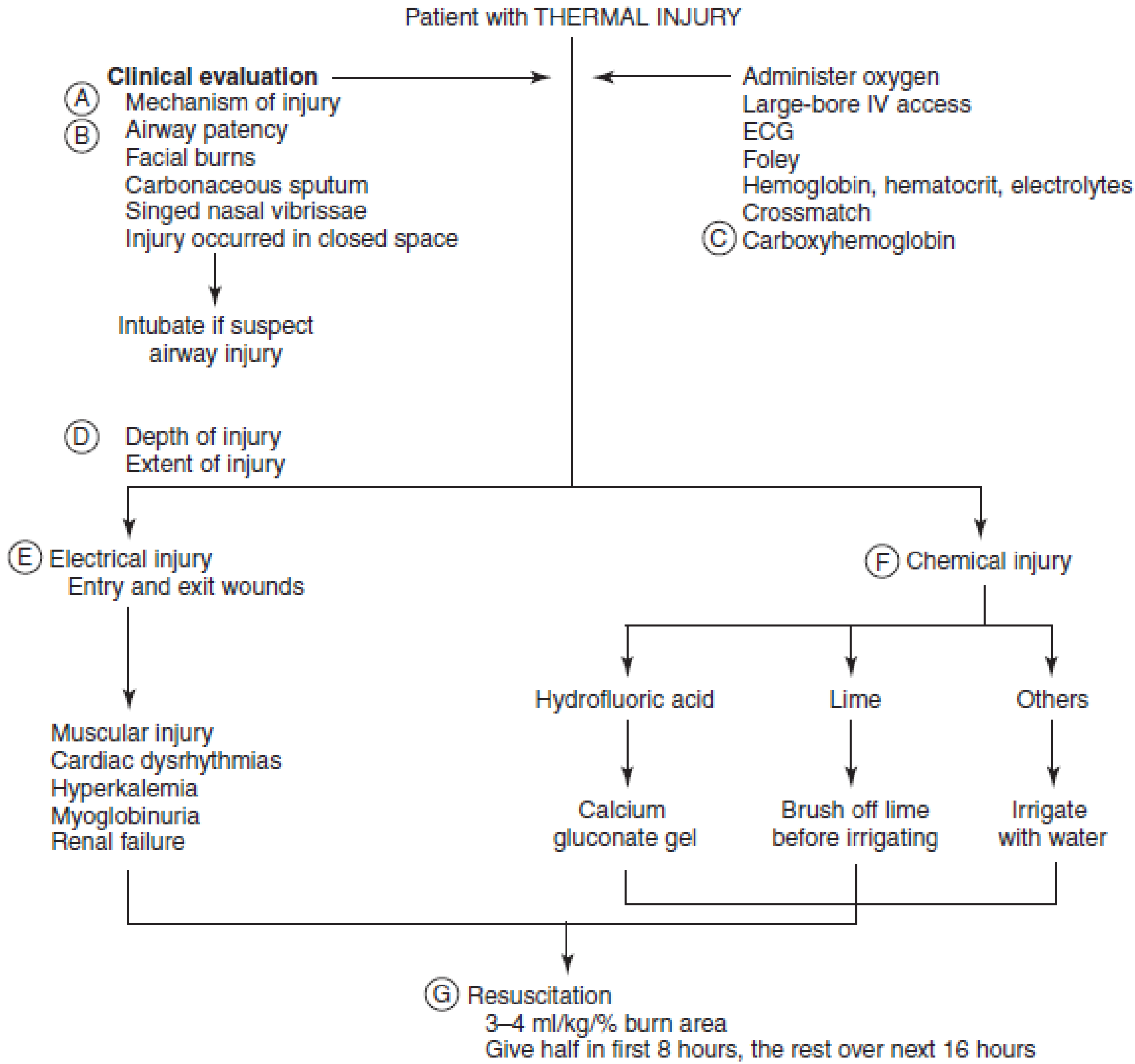
Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.

Awakening

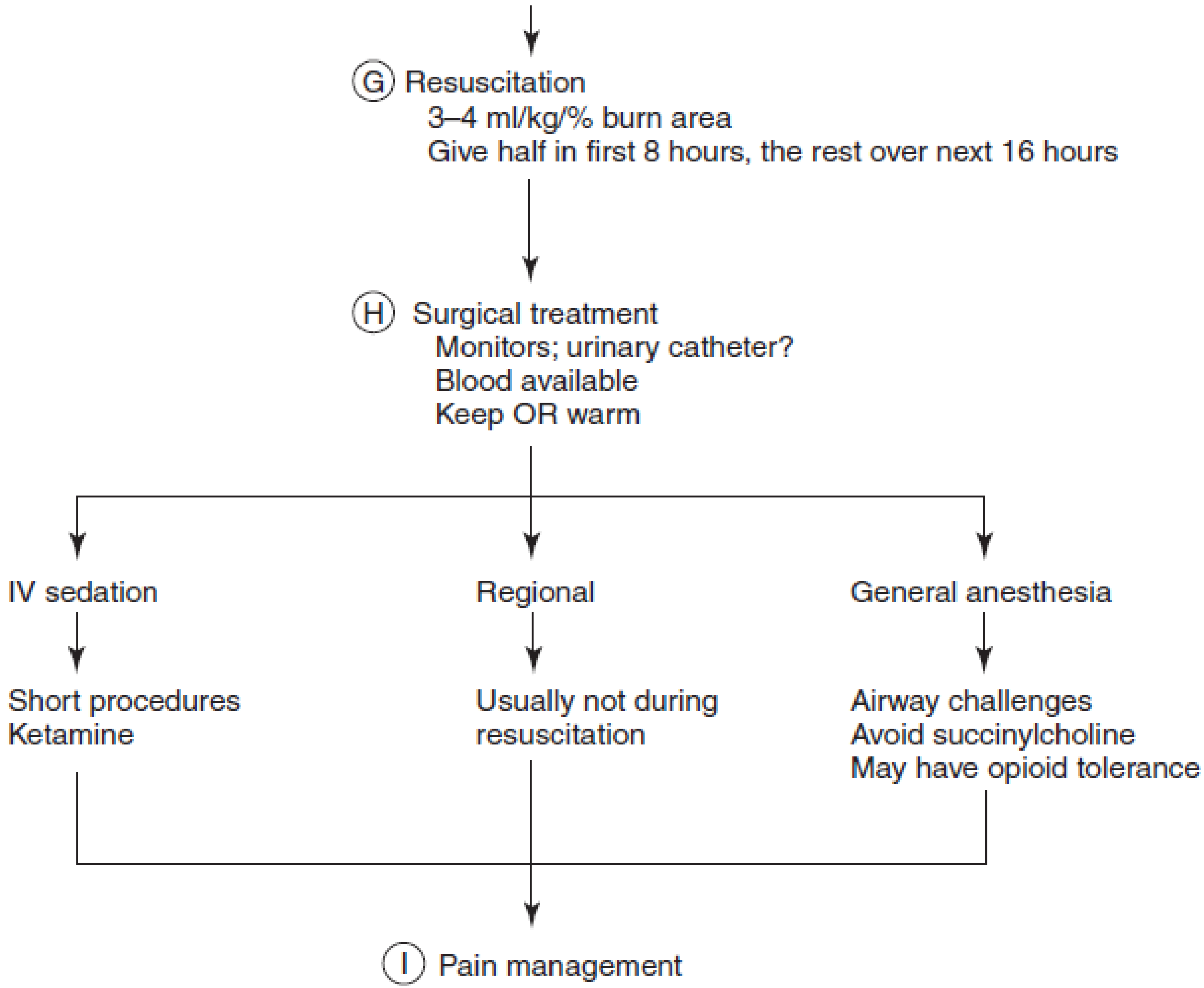
- Adequacy of air exchange & patency of the airway
- Analgesic drugs

Clinical State	Background Anxiety	Background Pain	Procedural Anxiety	Procedural Pain	Transition to Next Clinical State
Mechanically ventilated acute burn	Midazolam infusion	Morphine sulfate infusion	Midazolam intravenous titration	Morphine sulfate intravenous titration	Wean infusions 10-20% per day and substitute nonmechanically ventilated acute guideline
Nonmechanically ventilated acute burn	Scheduled enteral lorazepam	Scheduled enteral morphine sulfate	Lorazepam intravenous titration or enteral dose	Morphine sulfate enteral or intravenous titration	Wean scheduled drugs 10-20% per day and substitute chronic acute guideline
Chronic acute burn	Scheduled enteral lorazepam	Scheduled enteral morphine sulfate	Lorazepam enteral dose	Morphine sulfate enteral dose	Wean scheduled and bolus drugs 10-20% per day to outpatient requirements and pruritus medications
Reconstructive surgical patient	Scheduled enteral lorazepam	Scheduled enteral morphine sulfate	Lorazepam enteral dose	Morphine sulfate enteral dose	Wean scheduled drugs and bolus drugs to outpatient requirement

Charl J. Cote, A practice of anesthesia for infant and children, Chapter 34: Burn injuries, 2009.



Lois L. Bready, Decision making in anesthesiology, 4th ed.,2007.



Lois L. Bready, Decision making in anesthesiology, 4th ed.,2007.

SPECIAL CONSIDERATIONS FOR **ELECTRICAL BURNS**

- classified ; - low voltage (≤400 V) ; Home
  - high voltage (>1000 V) ; Industries

  The visible injury may be only the tip of the iceberg

- Major problems in major electrical/**lightening** burns = cardiac arrhythmias and/or damage to muscle → free Hb & myoglobin → hemoglobinuria & myoglobinuria

- Rx by
  - maintaining high urine output (1-2 mL/kg/hr)
  - Mannitol
  - Sodium bicarbonate (alkalinize the urine)

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Anesthesia for Children with Burns

1. AIRWAY & VENTILATORY MANAGEMENT
   - Awake intubation or ketamine (1 to 1.5 mg/kg) →sedate the child while maintaining spontaneous ventilation
   - Tracheostomy is the airway of choice for a child with deep burns of the lower face or who are anticipated to require > 2 - 3 wks of mechanical ventilation

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

2. FLUIDS

Modified Parkland formula:

4 cc of RLS / kg / %TBSA / 24 hrs

- formulas are only guidelines & provide a starting point
- Rates of fluid administration should be titrated to maintain a urine output of 1 mL/kg/hr
- Once resuscitation is complete, fluids can be decreased to a maintenance rate that takes into account the burn size & extra evaporative losses that are expected

$$[(\%\ \text{TBSA burned} + 35) \times \text{BSA}(m^2) \times 24] + 1500\ \text{mL}/m^2$$

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

PERIOPERATIVE MANAGEMENT

1. PERIOPERATIVE EVALUATION

   focused on areas most likely to be adversely affected by the burn injury

- airway, respiratory system, cardiovascular system, volume status
- assessment of sites for monitoring; BP, EKG, pulse oximetry, temperature
- review of the past anesthetic records
- Ventilator settings
- Intravenous access

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

PERIOPERATIVE MANAGEMENT

1. PERIOPERATIVE EVALUATION

- Laboratory values ; acid-base balance, Hct, calcium, electrolytes
- initiating transfusion in advance of the procedure
- recent CXR
- Most important, discuss the proposed anesthetic management with the child 's family

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

2. INDUCTION AND AIRWAY MANAGEMENT

- Transport with prevent heat loss
- standard monitors placed before induction
- induction agent may be used with careful titration to effect (ketamine)
- If difficult airway maintenance or intubation is anticipated →spontaneous ventilation should be maintained until the airway is secured

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

3. MAINTENANCE OF ANESTHESIA

dictated by the child's overall clinical condition

- nitrous oxide/opioid, ketamine, propofol, volatile agent
- Adequate pain control, warm environment, early wound closure

4. INTRAOPERATIVE BLOOD LOSS

- blood & blood products should be warmed due to rapidity of transfusion
- estimating that 3% of BV is lost for every 1% of BSA excised
- Burns of the face, head, and neck produce even greater blood loss
- During skin graft = 2% of BV lost for every 1% of body grafted

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

5. POSTOPERATIVE PAIN CONTROL

- donor site pain is the most intense
  → Rx; 2 -2.5 mg/kg of bupivacaine LA

- infusions of opioids, anxiolytics, other sedatives

Motoyama & Davis: Smith's Anesthesia for Infants and Children, Chapter 29: Anesthesia for Children with Burns 7th ed. 2005.

Conclusions

- Caution for **inhalation injury**→Airway obstruction
- No single physiologic endpoint is always reliable to judge adequacy of **fluid resuscitation**
- **Circulatory failure** in major burns occurs in 2 stages
  - initial stage of “burn shock”
  - stage of hyperdynamicity & hypermetabolism

Conclusions

- After the first 24 hours, **succinylcholine** must be avoided for as long as 2 year
- **Drug** responses are variable & unpredictable → careful titration of doses to desired effects
- **Hypothermia** is a risk in the operating room

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