BITTNER EA, ET AL,

ACUTE AND PERIOPERATIVE CARE OF THE BURN-INJURED PATIENT

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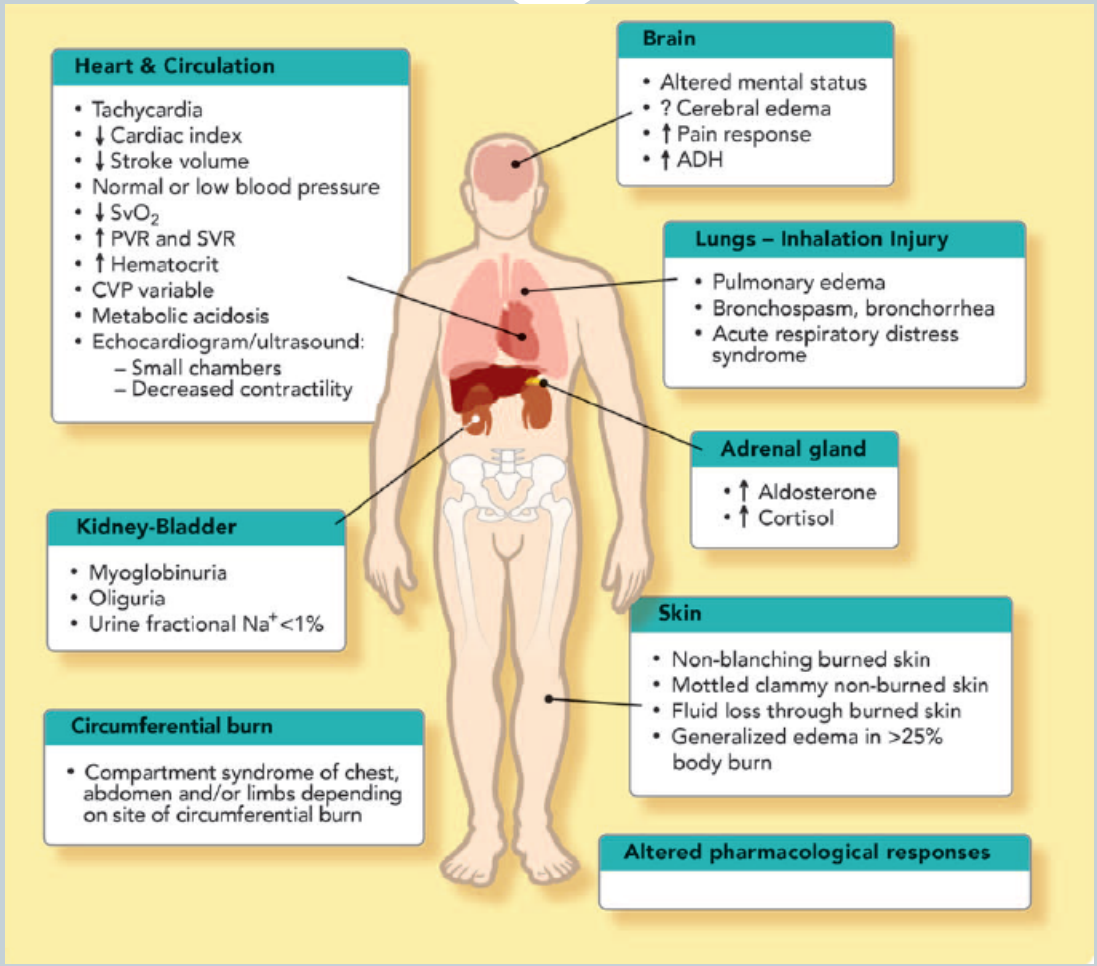
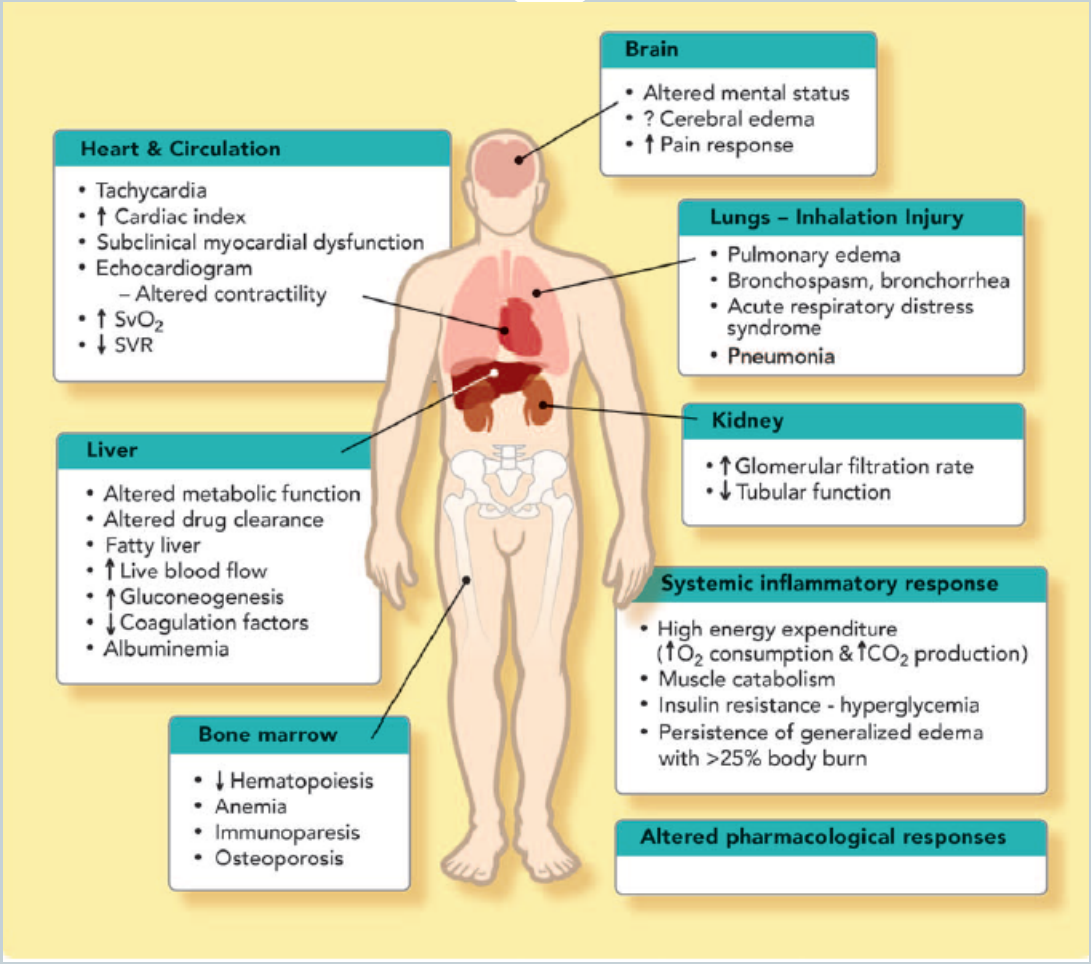
BURN INJURY PATHOPHYSIOLOGY

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



(>48 hrs)Pathophysiological Changes During Hypermetabolic/ hyperdynamic Phase of Burn



Pathophysiologic Changes During Early and Late Phases of Major Burn Injury

	Early phase	Late phase
Cardiovascular	Hypovolemia, ↓ cardiac output, ↑ SVR	↑ cardiac output, tachycardia, systemic HTN
Pulmonary	Airway obstruction and edema, pulmonary edema	Chest wall restriction due to scar formation
	Carbon monoxide poisoning	Tracheal stenosis due to repeat/prolonged intubation
Renal	↓ Glomerular filtration rate, myoglobinuria	↑ Glomerular filtration rate, ↑ tubular dysfunction
Endocrine and metabolic		↑ Metabolic rate, ↑ core body temperature, ↑ muscle catabolism
		↑ Insulin resistance, ↑ lipolysis, ↑ glucolysis
		↓ Thyroid and parathyroid hormones
Hepatic	↓ Perfusion	↑ Perfusion, ↑ metabolism
Hematologic	Hemoconcentration, hemolysis, thrombocytopenia	Anemia
Gastrointestinal	↓ Perfusion with mucosal damage	Stress ulcers, adynamic ileus
Neurologic	↑ Cerebral edema, ↑ intracranial pressure	Hallucination, personality change, delirium, seizure, coma

Abbreviations: ↓, decreased; ↑, increased; SVR, systemic vascular resistance; HTN, hypertension.
(Adapted from MacLennon et al[8] and Fuzaylov and Fidkowski.[11])

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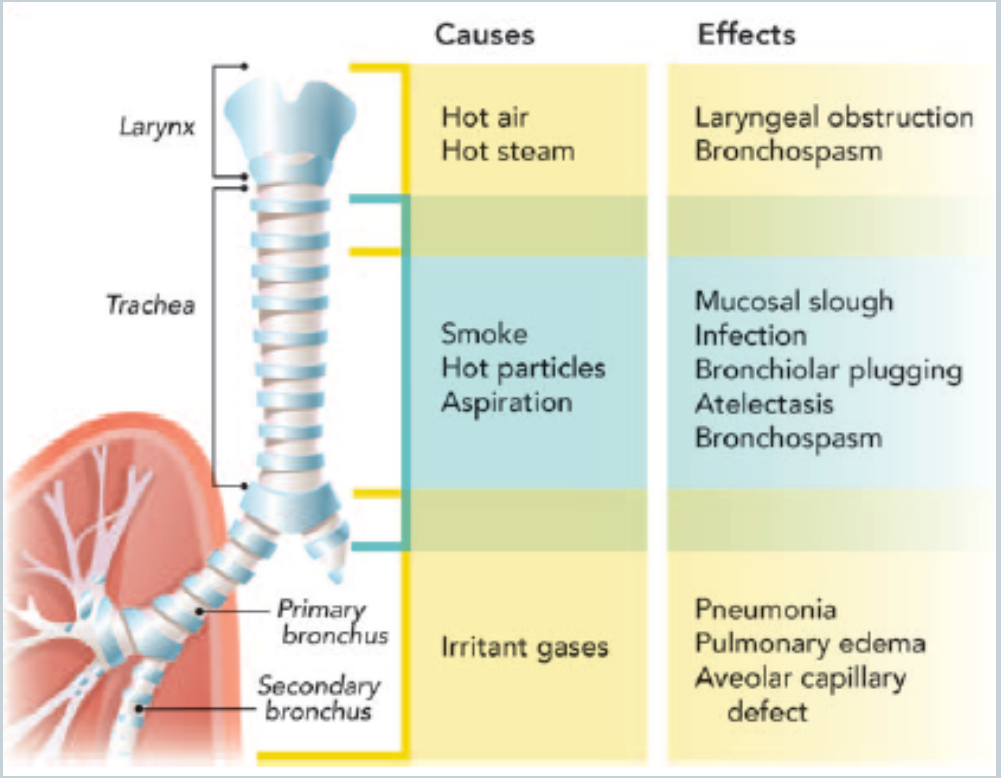
INHALATION INJURY

Respiratory injury from Burns



Symptoms of Acute Carbon Monoxide Toxicity Based on Blood Carboxyhemoglobin Level

COHb (%)	Symptom
< 10	Usually asymptomatic, may have headache
> 20	Headache, dizziness, confusion, visual disturbances, dyspnea, and nausea
> 40	Coma and seizures due to cerebral edema
> 60	Cardiopulmonary dysfunction and death

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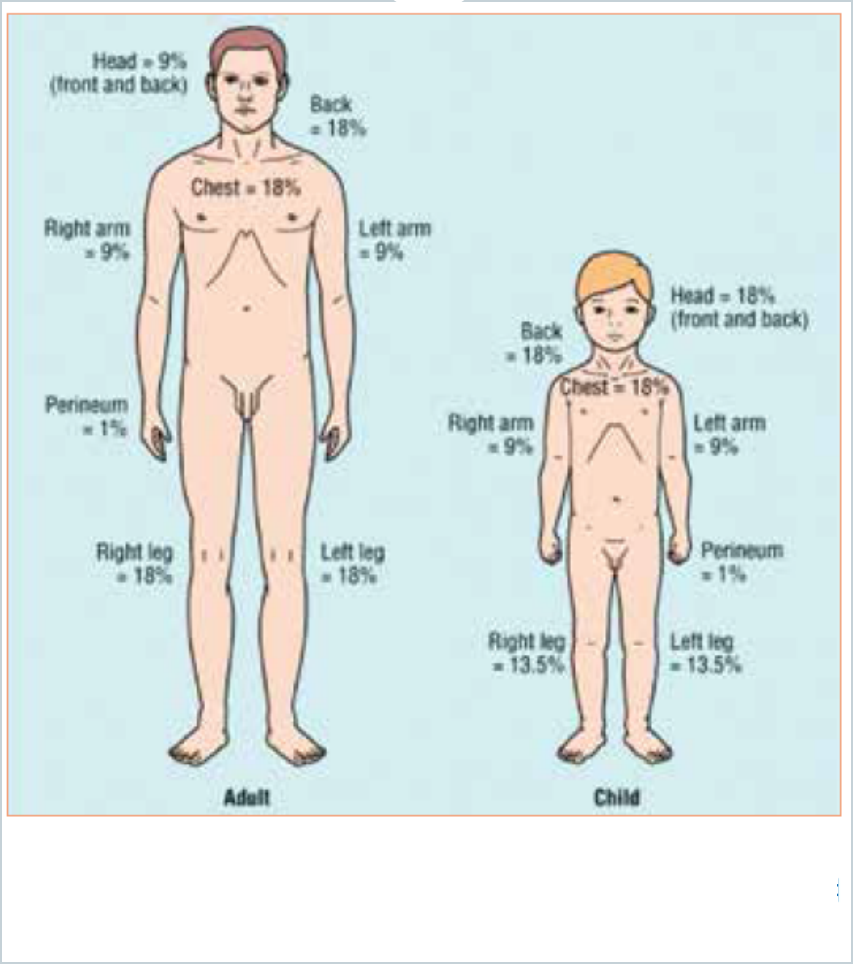
ELECTRICAL INJURY

INITIAL EVALUATION

Wallace Rule-of-Nine Method for the Assessment of Total Body Surface Area Burned



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Lund–Browder burn diagram

Burn Estimate and Diagram Age and Area

Initital evaluation*

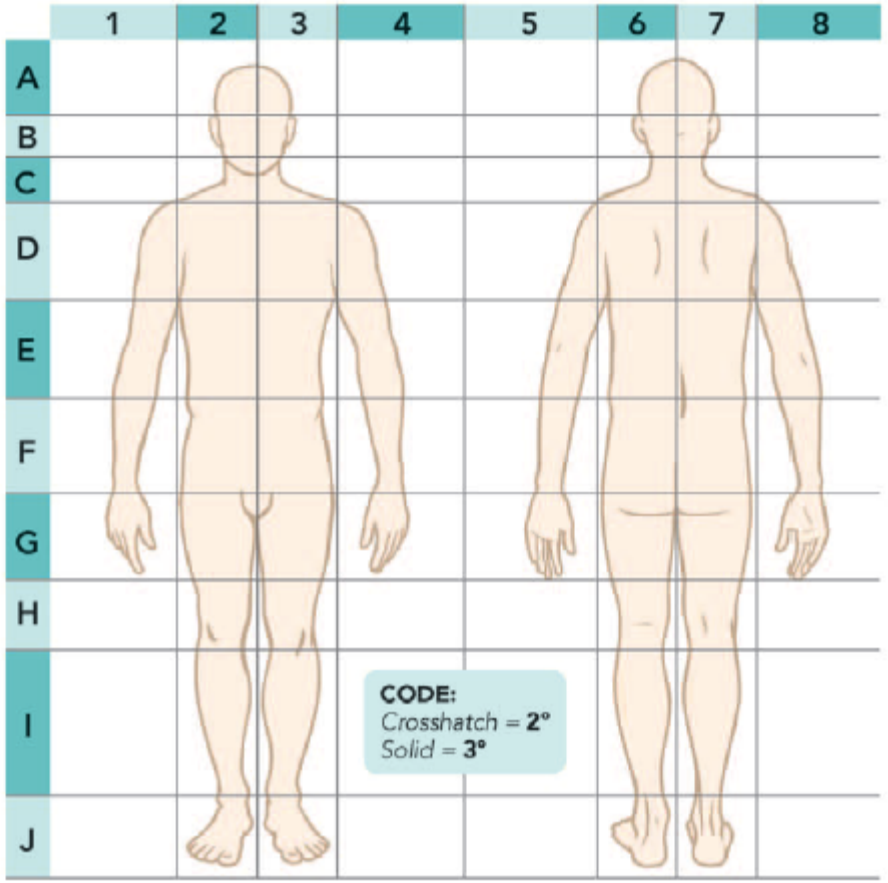
Signature: _____

Date of burn: _____

Date completed: _____

*To be completed by the admitting physician or Licensed Independent Practitioner on admission

This is a working burn estimate diagram only, and is not as accurate as photography.



Lund–Browder burn table

Area	Birth-1 yr.	1-4 yrs.	5-9 yrs.	10-14 yrs.	15 yrs.	Adult	2°	3°	TOTAL
Head	9	17	13	11	9	7			
Neck	2	2	2	2	2	2			
Anterior trunk	13	13	13	13	13	13			
Posterior trunk	13	13	13	13	13	13			
Right buttock	2.5	2.5	2.5	2.5	2.5	2.5			
Left buttock	2.5	2.5	2.5	2.5	2.5	2.5			
Genitalia	1	1	1	1	1	1			
Right upper arm	4	4	4	4	4	4			
Left upper arm	4	4	4	4	4	4			
Right lower arm	3	3	3	3	3	3			
Left lower arm	3	3	3	3	3	3			
Right hand	2.5	2.5	2.5	2.5	2.5	2.5			
Left hand	2.5	2.5	2.5	2.5	2.5	2.5			
Right thigh	5.5	6.5	8	8.5	9	9.5			
Left thigh	5.5	6.5	8	8.5	9	9.5			
Right lower leg	5	5	5.5	6	6.5	7			
Left lower leg	5	5	5.5	6	6.5	7			
Right foot	3.5	3.5	3.5	3.5	3.5	3.5			
Left foot	3.5	3.5	3.5	3.5	3.5	3.5			
***Only 2° and 3° burns are included in the total TBSA burn percent*						TOTAL			

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

American Burn Association
Burn Injury Severity Grading System

Minor burn	Moderate burn	Major burn
Criteria		
< 10% TBSA burn in adults	10%-20% TBSA burn in adults	> 20% TBSA burn in adults
< 5% TBSA burn in young or old	5%-10% TBSA burn in young or old	> 10% TBSA burn in young or old
		> 5% full-thickness burn
< 2% full-thickness burn	2%-5% full-thickness burn	High voltage injury
	High voltage burn	Known inhalation injury
	Suspected inhalation injury	Significant burn to face, eyes,
	Circumferential burn	ears, genitalia, hands, feet
	Medical problem predisposing to	or joints. Significant associated
	infection (eg, diabetes mellitus,	injuries (eg, fracture
	sickle cell disease)	or other major trauma)
Disposition		
Outpatient	Admit to hospital	Refer to burn center

Abbreviation: TBSA, total body surface area.
(Adapted from American Burn Association[6] and Morgan et al.[7])

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FLUID RESUSCITATION

Fluid Resuscitation Formulas

Formula	Fluid in 1st 24 h	Crystalloid in 2nd 24 h	Colloid in 2nd 24 h
Parkland	LR, 4 mL/kg per % TBSA	20%-60% estimated plasma volume	Titrated to UO of 30 mL/h
Evans	NS, 1 mL/kg per % TBSA	50% of 1st 24-h volume and D_5W, 2L	50% of 1st 24-h volume
Slater	LR, 2 L and FFP, 75 mL/kg		
Brooke	LR, 1.5 mL/kg per % TBSA Colloid, 0.5 mL/kg per % TBSA and D_5W, 2 L	50% of 1st 24-h volume and D_5W, 2L	50% of 1st 24-h volume
Modified Brooke	LR, 2 mL/kg per % TBSA		
MetroHealth (Cleveland)	LR, 4 mL/kg per % TBSA and $NaHCO_3$, 50 mEq	0.45% NS titrated to UO	1 U FFP per liter 0.45% NS and D_5W as needed for hypoglycemia

Abbreviations: UO, urine output; LR, lactated Ringer's solution; FFP, fresh frozen plasma; NS, normal saline; D_5W, dextrose 5% (5 g dextrose/100 mL water).

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

Parkland formula: $4 \times 70 \times 60 = 16{,}800$ ml of LR/24 h;

Brooke formula: $1.5 \times 70 \times 60 = 6{,}300$ ml of LR/24 h;

$0.5 \times 70 \times 60 = 2{,}100$ 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.

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Indicators of Adequate Circulating Volume and/or Resuscitation

Urine output	0.5–1.0 ml · kg^{-1} · 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 (suggests hypoperfusion in the absence of carbon monoxide or cyanide poisoning)

*Blood pressure can be normal even with hypovolemia because of vasoconstriction produced by catecholamines and antidiuretic hormone (vasopressin). †Heart rate can be high, despite normovolemia because of catecholamines, anxiety and/or pain, and hypermetabolic state. ‡Central venous pressures can be artificially altered by airway pressures, pleural or pericardial fluid, or abdominal distension. §$\text{FeNa} = 100 \times \frac{\text{Sodium – urinary} \times \text{creatinine – plasma}}{\text{Sodium – plasma} \times \text{creatinine – urinary}}$. ‖Blood urea nitrogen (BUN) to creatinine (Cr) ratio.

ANESTHETIC MANAGEMENT

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

Intraoperative Management

- Airway Management
- Vascular Access
- Ventilatory Management

Anesthetic Considerations for Patients With Burn Injuries

Fluids	Crystalloids are mainstay of therapy during early phase of burn injury; consider colloids > 24 hours after burn injury.
Succinylcholine	Succinylcholine okay within < 24 hours of burn injury; avoid if > 24 hours and for at least 18 months after burn injury.
Nondepolarizing muscle relaxants	↑ Dose frequency and requirements (2- to 5-fold) during hyperdynamic phase, reversal agent requirements are unchanged.
	Consider rocuronium (up to 1.2 mg/kg) for rapid-sequence induction if > 24 hours after burn injury.
IV anesthetics	↓ Dose requirements during early phase; ↑ Dose requirements during hyperdynamic phase of injury.
	Consider multimodal therapy (eg, opioids, propofol, ketamine, benzodiazepines).
Inhalation agents	↓ MAC during early phase of burn injury; ↑ MAC during hyperdynamic phase of burn injury
	May be beneficial in the setting of inhalation injuries.
Beta blockers	Attenuates the hyperdynamic phase of burn injury
Insulin	Attenuates the hyperdynamic phase of burn injury

Abbreviations: ↑, increased; ↓, decreased; IV, intravenous; MAC, minimum alveolar concentration.

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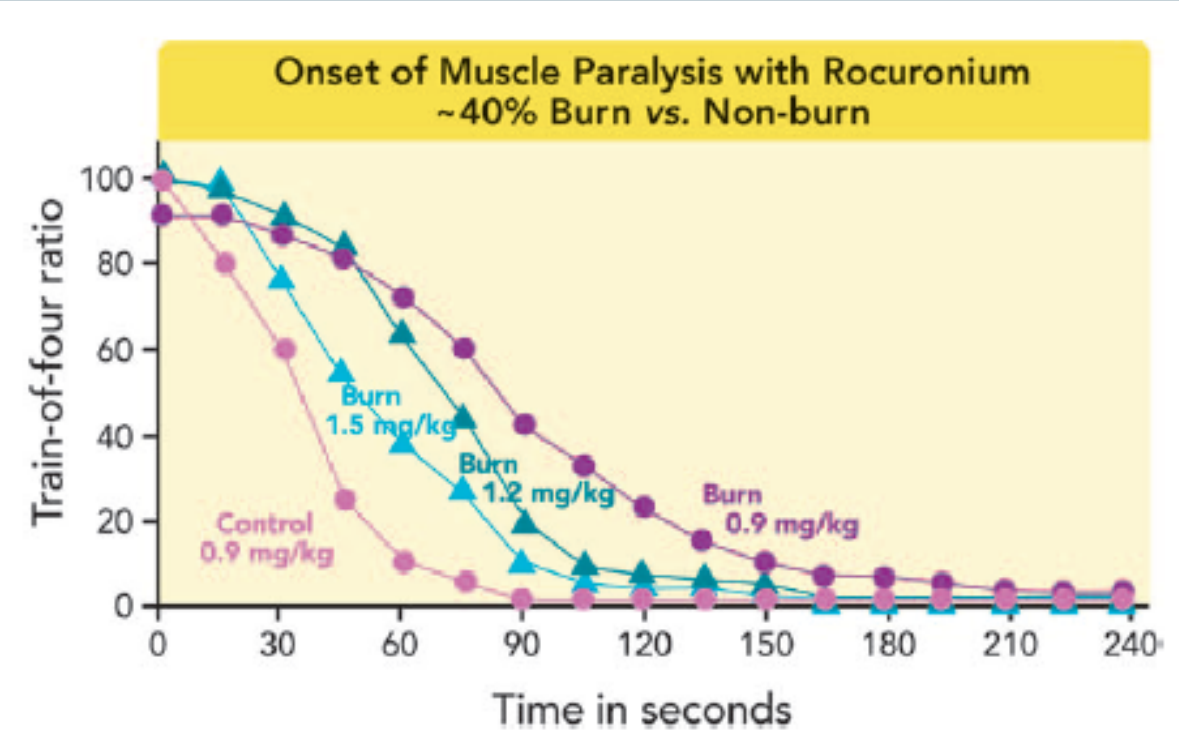
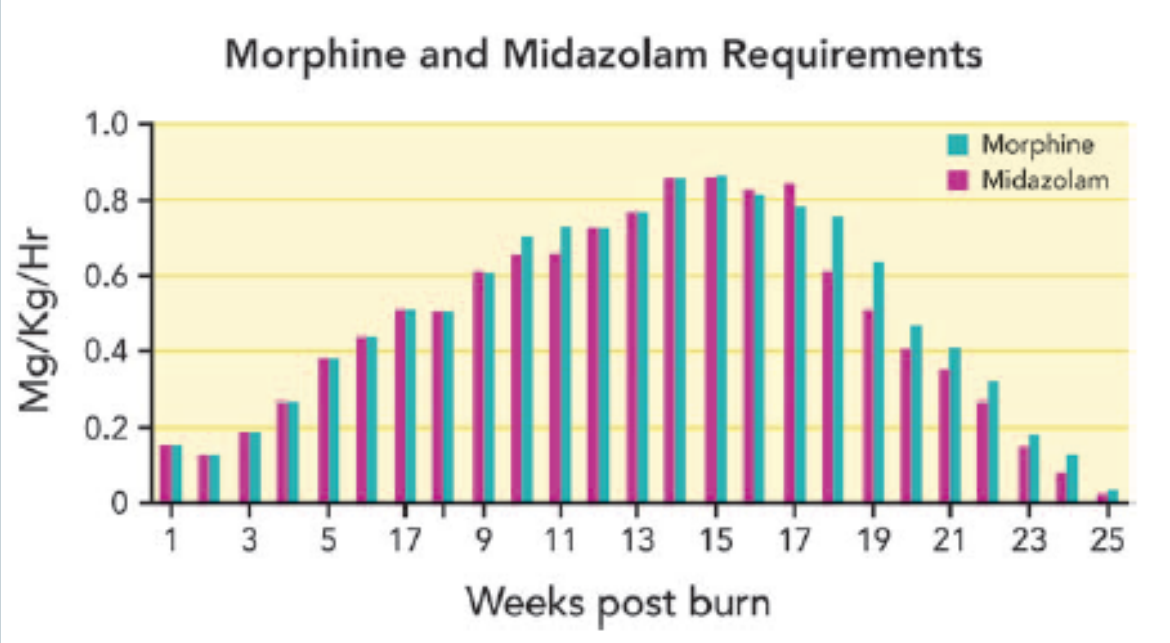
Dose–response curves and time to maximal effect of rocuronium in adult burned and nonburned patients



Burn injury–induced tolerance to narcotics and sedatives



Pharmacological Considerations

- Regional Anesthesia
- Metabolic and Nutritional Management

POSTOPERATIVE CARE

PAIN MANAGEMENT

Sedation and Analgesia Guidelines for Acute Burns

Stage of Injury	Background Anxiety	Background Pain	Procedural Anxiety	Procedural Pain
Acute burn ventilated	#1 Midazolam infusion	Morphine infusion	Midazolam boluses	Morphine boluses
	#2 Dexmedetomidine infusion	Morphine infusion	Dexmedetomidine higher infusion rate	Morphine boluses
	#3 Antipsychotics	Morphine infusion	Haloperidol (very slow) boluses	Morphine boluses
	#4 Propofol infusion (<48 h)	Morphine infusion	Propofol boluses	Morphine boluses
Acute burn not ventilated	Dexmedetomidine IV or scheduled lorazepam IV or PO	Morphine IV or PO	Lorazepam IV/PO	Morphine IV/PO or Ketamine IV
Chronic acute burn	Scheduled lorazepam or antipsychotics (PO)	Scheduled morphine or methadone	Lorazepam or antipsychotics (PO)	Morphine PO or oxycodone

Fentanyl infusions could be substituted for morphine infusions. In view of the increased incidence of delirium with benzodiazepines, minimal use of them is advocated.

IV = intravenous; PO = per oram (by mouth).

SUMMARY

- Pathophysiological Changes: Ebb – Flow
- Airway and/or Lung edema: fast and unpredictable
- Electrical Burns: high morbidity
- Formulae for Fluid Resuscitation: physiologic endpoints
- Intraoperative Management
- Pain Management: higher opioid and sedative doses