

- Use crystalloids, red blood cells, and fresh frozen plasma judiciously to maintain normal blood volume and composition and avoid worsening edema.

Regional Anesthesia

- Can be used for analgesia after determining cause and extent of any neurologic sequelae and excluding possibility of a compartment syndrome
- May be used for anesthesia during minor procedures; donor sites are more painful than grafted sites and should be blocked preferentially

Postoperative Period

- Standard extubation criteria should be followed, paying special attention to total fluids given and the possibility of airway edema.
- Increased analgesic demands. Consider physical ability to activate PCA before instituting it.
- Monitor carefully during transport, especially in critically ill pts.

Anticipated Problems/Concerns

- Minimize the possibility of renal failure by maintaining adequate urine output and alkalinizing the urine.

- Monitor edema during surgery because the tracheal tube tape may become a facial tourniquet or the tube may migrate outside glottis.
- Pts who develop sepsis or multiorgan failure have worse outcomes.
- Burn pts have an increased incidence of infection. Therefore, meticulous aseptic care during line placement, intubation, and all invasive procedures is essential.

Burn Injury, Flame

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Risk

- Flame injuries accounted for 43% of all burn cases from 2003 to 2012.
- 70,000 flame injuries requiring treatment over same 10-y period.
- Approximately 70% of injuries are accidental and nonwork related.
- Approximately 70% of injuries occur at home.

Perioperative Risks

- Major predictors of mortality include BSA >40%, age >60, and presence of inhalation injury.
- Predicted mortality is 0.3%, 3%, 33%, or 90%, depending on presence of zero, one, two, or three of the above-mentioned risk factors.
- Up to one-third of pts with inhalation injury will develop acute airway obstruction.
- Other incidental traumatic injuries may be present.

Worry About

- Airway protection and ventilation
- Hypovolemia with early goal-directed volume resuscitation as the single most important therapeutic intervention
- Hypothermia

Overview

- Direct thermal energy produces direct cellular destruction and coagulative necrosis.
- Systemic microvascular integrity is lost in massive inflammatory response; proteins are lost into interstitial space.
- Significant shift of fluids, electrolytes, and proteins into the interstitium occurs with rapid equilibrium of intravascular and interstitial compartments.
- Changes reflected by massive edema formation and loss of circulating plasma volume, hemoconcentration, decreased urine output, and depressed CV function.
- Cardiac output is reduced due to hypovolemia, decreased contractility, and increased afterload.
- Most edema occurs at the burn site and is maximal at 24 h after the injury. Edema results in tissue hypoxia and increased tissue pressure with circumferential injuries.

Etiology

- American Burn Association stratifies thermal injury etiologies as fire, hot liquids, contact with hot objects, and electrical sources. Flame burns are the most lethal of all thermal injuries.

Usual Treatment

- Most important points of initial phase are assessment of current (and prediction of subsequent) airway patency and documentation of the presence or absence of inhalation injury.
- Early intubation likely if pt has face/inhalation injury or if BSA injured requires aggressive fluid resuscitation.
- Provide supplemental O₂ and monitor O₂ saturation in burn pts with significant injury. Most pts with large burns will require prompt ET intubation and mechanical ventilatory support.
- Prompt establishment of large-bore IV access and rapid initiation of fluid resuscitation. Parkland or “Universal” formula is most commonly used (4 mL/kg/BSA% over 24 h, with first half given over first 8 h).
- Insert urinary catheter early to monitor urine output as guide for volume status.
- Evaluate all extremities and chest wall for potential compartment syndrome requiring fasciotomy or escharotomy for urgent release.
- Multiple skin grafting procedures may be necessary during admission.
- Early debridement of eschar is performed to minimize infection; dead tissue readily supports bacterial growth.

Assessment Points				
System	Effect	Assessment by Hx	PE	Test
HEENT	Face and airway burns	Dysphonia, dysphagia Reports of fumes or extraction from enclosed space	Singed facial or nose hair, carbonaceous sputum, facial burns	Oral inspection, laryngoscopy, bronchoscopy
CV	Arrhythmias, hypovolemic shock, myocardial depression	Palpitations, dyspnea Loss of consciousness, depressed mental status	Tachycardia or irregular rhythms, hypotension	ECG
RESP	Pneumonitis, ARDS, restrictive disease from eschar, carboxyhemoglobinemia	Cough, dyspnea, stridor	Hypoxemia, circumferential chest eschar	ABG, co-oximetry, chest radiograph
RENAL	Acute renal failure, ATN, electrolyte disturbances	Large BSA burns, crush injuries	Myoglobinuria, oliguria	Electrolyte profile (BUN/Cr), urine myoglobin, urinalysis
CNS	Hypoxemia	Loss of consciousness, confusion	Focused neurologic exam	ABG, co-oximetry
MS	Tissue destruction, rhabdomyolysis, compartment syndrome	Large BSA burns, overadministration of fluids	Evolving loss of motor and/or sensory function	Serum myoglobin, compartment or bladder pressure monitoring

Key References: Snell JA, Loh NH, Mahambrey T, et al: Clinical review: the critical care management of the burn patient, *Crit Care* 17(5):241, 2013; Bittner EA, Shank E, Woodson L, et al: Acute and perioperative care of the burn-injured patient, *Anesthesiology* 122(2):448–464, 2015.

Perioperative Implications

Preoperative Preparation

- Thermoregulation is impaired. Warm OR as much as possible before pt arrives. Use forced-air warming blankets and fluid warmers intraop.
- Anesthesia services may be requested for bedside debridement and other procedures.
- Assess location and adequacy of venous access.

- Document presence of other invasive devices (e.g., arterial catheter, ET or tracheostomy tubes, feeding tubes) and ventilatory settings.

Monitoring

- Standard monitors may be difficult to apply to extensive burns.
- Arterial line is advisable for extensive grafting procedures that can be long and involve significant blood loss.

- Central venous access may be necessary if peripheral access sites are burned. Lines should be preferentially placed through intact skin.

Airway

- Intubate with largest feasible ETT to aid pulm toilet, minimize mucus plugging, and decrease work of breathing. Need for postop mechanical ventilation is common.

Preinduction/Induction

- Succinylcholine should be avoided after acute phase (first 24 h after injury).
- Gastroparesis and high residual gastric volumes are common after injury; use aspiration precautions.
- Induction agent doses should be adjusted in the context of hypovolemic shock.

Maintenance

- Requirements for neuromuscular blockers usually increased; attributed to the increased binding sites at extrajunctional receptors.
- Pts may need significantly increased narcotics.
- Keep the OR room temperature at $\geq 85^\circ\text{F}$ to minimize heat loss and decrease metabolic rate.

- Communicate decreases in core body temperature to surgeons; case may be shortened to prevent severe hypothermia.

Extubation

- Consider extubation in early stages of management cautiously. Emergent reintubation may be very difficult due to edema.

Anticipated Problems/Concerns

- Most common complications include pneumonia, UTI, resp failure, cellulitis, and sepsis.
- Ventilator-associated pneumonia may develop in 70% of pts with inhalation injury.

- Pain management is usually challenging. Opioid doses often significantly exceed recommended standard dosing guidelines. Autograft donor sites are very painful; regional analgesia may be useful.
- ACS is a life-threatening complication caused by high-volume resuscitation. Extremity compartment syndromes can also result from extensive edema formation.
- Incidence of DVT in burn pts is increased (1-23%). Therefore, DVT chemoprophylaxis is routinely used.

Calcium Deficiency/Hypocalcemia

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Risk

- Common in critically ill pts and may be as high as 88% in ICU pts

Perioperative Risks

- Neuromuscular instability leading to seizure, laryngospasm, bronchospasm, or resp arrest
- Impaired cardiac function causing heart failure, hypotension, and dysrhythmias

Worry About

- Symptomatic hypocalcemia

Overview

- Normal serum calcium content: 8.5–10.5 mg/dL.
 - With 40–50% bound to plasma proteins (albumin).
 - With 45–50% ionized (physiologically active).
 - With 10–15% nonionized, bound to inorganic anions such as phosphate, citrate, and sulfate.
- Total calcium level related to albumin level and acid-base status affects the ionized calcium level.

- Ionized calcium level is the preferred measurement (normal: 4.75–5.3 mg/dL [1.19–1.33 mol/L]).
- The physiologic role of calcium:
 - Neuromuscular signaling and muscle contraction.
 - Hormone secretion.
 - Cardiac contractility.
 - Blood coagulation.
 - Cell growth.
 - Transport and/or secretion of fluids.

Etiology

- Hormonal
 - Hypoparathyroidism (intentional or unintentional surgical removal, hypomagnesemia, and "hungry bone syndrome")
 - Pseudohypoparathyroidism (decreased response to PTH)
 - Decreased vitamin D production/activity (decreased sunlight, hyperphosphatemia, and anticonvulsants)
- Ca^{2+} chelation (massive transfusion, cell lysis and phosphate release, and pancreatitis)
- Osteoblastic metastasis (prostate and breast cancers)
- Alkalosis (increased calcium binding to proteins)

- Congenital and autoimmune disease
- Most common causes of acute intraop hypocalcemia: Acute hyperventilation (resp alkalosis) and massive infusion of citrated blood products ($>1.5\text{ mL/kg/min}$)
- Can occur with persistent diarrhea and hypomagnesemia due to PPI treatment in a small number of pts

Usual Treatment

- Treat based on ionized calcium, not total calcium level.
- Asymptomatic hypocalcemia rarely requires treatment.
- Symptomatic hypocalcemia requires emergent treatment.
 - IV calcium chloride (300–500 mg) or calcium gluconate.
 - Follow with continuous replacement if needed.
 - Administered slowly because venous irritation can occur, with central venous administration preferred because calcium chloride can cause tissue necrosis if extravasated from a peripheral vein.
- Hypocalcemia often concurs with hypomagnesemia/hyperphosphatemia. Treat as needed.

Assessment Points

System	Effect	Assessment by Hx	PE	Test
CV	Involved in cardiac pacemaker activity and generation of cardiac action potential	Hx of dysrhythmia SOB (or other symptoms of heart failure)	Prolonged QT Hypotension Pulmonary vascular congestion	ECG Continuous cardiac monitoring CXR
HEME	Citrate in stored blood products chelates calcium	Massive transfusion of citrated blood products ($>1.5\text{ mL/kg/min}$)		Ionized calcium level
GI	GI smooth muscle spasm	Abdominal cramping		
RESP	Resp smooth muscle contraction/tetany	SOB Laryngospasm Bronchospasm	Hypoxia Stridor Wheezing Resp arrest	Pulse oximetry
NEURO	Essential for all muscular movement Involved in the muscular excitation/contraction coupling	Muscle spasm Seizure Depression Psychosis Neuromuscular irritability Circumoral numbness Tingling in fingers/toes	Facial grimacing Seizure Papilledema (secondary to increased intracranial pressure) Irritability	Chvostek sign (twitch of circumoral muscles with tapping of the facial nerve anterior to the ear) Trousseau sign: Carpal spasm induced by inflation of BP cuff to 20 mm Hg above systolic BP for 3 min
DERM			Dry, scaly skin Brittle nails	

Key References: Khosla S: Hypercalcemia and hypocalcemia. In Kasper D, Fauci A, Hauser S, et al, editors: *Harrison's principles of internal medicine*, ed 19, New York, 2015, McGraw-Hill; Edwards MR, Grocott MPW: Perioperative fluid and electrolyte therapy. In Miller R editors: *Miller's anesthesia*, ed 8, Philadelphia, 2015, Elsevier, pp 1767–1810.

Perioperative Implications**Preinduction/Induction/Maintenance**

- Correct symptomatic hypocalcemia preop.
- Goal of treatment to eliminate symptoms, not necessarily return calcium levels to normal range.

Monitoring

- Serial ionized calcium measurements
- Continuous ECG monitoring

General Anesthesia

- Negative inotropic effects of anesthetic medications may become more pronounced.

Regional Anesthesia

- Hypocalcemia results in increased neuronal membrane irritability/tetany.
- Paresthesia a common finding.