Burn Injury, Electrical

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Risk

- Low-voltage burns (<1000 V) commonly occur in children at home.
- High-voltage burns (≥1000 V) are more common in adults and characteristically occur in outdoor environments near power sources and lines.
- Lightning electrical burns carry highest rate of mortality and usually have energy >30 million volts.

Perioperative Risks

- Pts with an acute burn or a history of burns may present an additional challenge to securing the airway. Fluid resuscitation in acutely burned pts may cause severe facial and airway edema; pts with a history of burns, especially facial, may have limited mouth opening and neck extension.
- Difficult IV access is a common problem. Two large-bore IVs are commonly needed for major burn surgery; however, depending on length of stay and surface area burn, central access and intra-arterial monitoring of blood pressure may be necessary.

Worry About

- Arrhythmias and cardiac arrest from direct electrical energy or metabolic derangements.
- Respiratory failure and edematous airway; respiratory failure may occur from tetany of respiratory muscles or cerebral injury.
- Blunt injuries, fractures, and dislocations if patients were jolted from electrical shock or fell from high structures.
- Compartment syndrome: Delayed exploration and decompression may result in increased amputation rates along with increased organ failure and mortality.
- Rhabdomyolysis and myoglobinuria from muscle injury leading to acute kidney injury.
- Hypothermia remains a serious concern despite that electrical injuries may not result in a large surface area burn.
- Acute hyperkalemia due to large muscle destruction and cellular breakdown.

Overview

- Severity of electrical burn depends on current, route taken by the current, and the duration of contact with the electrical source.
- Entry wounds occur often in the hands, with a leathery, charred appearance. Exit wounds are often explosive.
- Extent of injury may be misleading, as the visibly burned area is often small. Large amounts of destroyed tissue may be present under normal-appearing skin, leading to under resuscitation.
- Signs of electrical injury include loss of consciousness, extremity mummification, loss of pulses in an extremity, myoglobinuria, elevated serum creatinine kinase, and cardiac arrest.
- The electrical current in most households is between 110–220 V, which may produce a low-voltage burn and dysrhythmias. High-voltage burns often cause immediate cardiac arrest and/or respiratory paralysis.
- Direct lightning strikes are rarely survivable.

Etiology

- Of all burns, 3–5% are electrical.
- Causes vary greatly from electrical appliances in water to work-related accidents.
- Children may be involved in low-voltage burns at home. One cause is chewing electrical cords, causing oral mucosa burns.

Usual Treatment

- If ventricular fibrillation or asystole is present, CPR must be immediately initiated. If initial dysrhythmias are present, continuous cardiac monitoring is required because most serious dysrhythmias occur within 24 h. If dysrhythmia not present on arrival and no cardiac arrest occurs at the scene, further cardiac monitoring is not necessary.
- Secure airway if needed and obtain appropriate IV access.
- If myoglobinuria present, maintain urine output >2 mL/kg/h with generous hydration. Consider sodium bicarbonate infusion to alkalize urine and mannitol or furosemide to help maintain urine output.
- Escharotomy and fasciotomy may be required for vascular or nerve decompression.
- Indications for surgical decompression include progressive neurologic dysfunction, vascular compromise, increased compartment pressure, and systemic clinical deterioration from suspected ongoing myonecrosis.

Assessment Points

System	Effect	Assessment by Hx	PE	Test
DERM	Burn injuries, edema, compartment syndrome	Prehospital information, mechanism of injury	Remove all clothing to determine nature and extent of injury; check peripheral pulses	Measurement of compartment pressures (fasciotomy when >30 mm Hg, diastolic pressure minus tissue pressure <30 mm Hg)
CV	Arrhythmias, hypovolemia	Arrest in the field, ventricular fibrillation, high-voltage burn	Hypotension, bradycardia, or tachycardia	ECG
RESP	Paralysis, edema	Lightning or high-voltage injury	Signs of hypoxia	ABG, pulse oximetry
HEME	Hemolysis, vascular thrombosis, dehydration	Extensive tissue injury	Edema, extensive burns	Hematocrit
RENAL	Acute kidney injury	More frequent in high-voltage injuries	Large muscle destruction and tissue necrosis	Urine myoglobin, BUN/Cr, FEN_a, serum electrolytes
NEURO	Peripheral and central neuropathies	Injury that crosses midline, limb compartment syndrome	Neurologic deficits	MRI, nerve-conduction studies

Key References: Lovich-Sapola JA: Anesthesia for burns. In Smith CE, editor: *Trauma anesthesia,* ed 2, Cambridge, 2015, Cambridge University Press, pp 666–688; Bittner EA, Shank E, Woodson L, et al: Acute and perioperative care of the burn-injured patient, *Anesthesiology* 122:448–464, 2015.

Preoperative Implications

Preinduction

- Burn pts have increased metabolic rate; NPO time should be kept to a safe minimum. Consider continuing enteral feeds shortly up to surgery if the airway is secured and no airway invention is planned.
- Discuss with surgeon the extent of surgery to anticipate amount of blood loss.
- Maintain careful airway evaluation due to increased risk for airway edema and skin or muscle rigidity because of burns.
- Labs, including blood gases, K^+, and blood type and cross-match.
- Large-bore IV access may be needed in cases of complex debridement/grafting. Ultrasonography is recommended for obtaining central venous access.

General Anesthesia

- Selected for most large skin graft procedures
- Many pts already receiving ventilation support
- Recommended for cases in which large blood loss anticipated

Monitoring

- Use standard ASA monitors. It may be difficult to place monitors on burned surfaces. Use of staples and/or sutures to secure ECG leads or catheters may be required.
- Arterial monitoring may be necessary for extensive procedures or for pts receiving prolonged ventilatory support. Ultrasonography can facilitate arterial cannulation.
- Maintaining normothermia is a major challenge. Ambient temperature in OR must be raised. Use of fluid warmers and sterile forced-air warmers may be required.

Induction

- Induction agents such as ketamine may be useful in pts not already receiving ventilatory support. However, as with any of the other induction agents, it can result in myocardial depression in the catecholamine-depleted pt.
- In thermal burn pts, succinylcholine is contraindicated after 24–48 h from their injury. One must be cautious in electrical burn injury because severe muscle destruction may result in hyperkalemia. In this scenario, succinylcholine is contraindicated even at the injury's outset. Larger than usual doses of nondepolarizing muscle relaxants are frequently required for adequate muscle relaxation.

Maintenance

- Choice of inhaled anesthetic does not alter outcome.
- Larger doses of narcotics may be needed because burn pts often develop tolerance to opiates. The analgesic properties of ketamine make it a good choice for induction. Preop opioid infusions may be continued during surgery, with adjunct boluses for increased analgesic requirements.
- Lung-protective ventilatory strategy with tidal volumes ≤6 mL/kg (predicted body weight) and PEEP should be used. Increased respiratory rate and permissive hypercapnia may be required.

- 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 O_2 and monitor O_2 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.