Electrocution and Electrical Cord Injury

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Electrocution is a rare occurrence in adult dogs and cats but is a more common pediatric emergency in veterinary medicine. Electrocution in small animals is most often the result of chewing on electrical cords, although it may rarely occur through exposure to noninsulated wires or downed power lines or from lightning strikes.

The type and severity of electrical injury may vary considerably among patients depending on the location on the body and the amperage involved. Amperage is determined by the voltage of the source and the resistance of the animal's body (Ohm's Law: Current in Amperes = Voltage of Source/Resistance). Injury becomes more severe with electrocutions involving either higher voltage or less resistance to electrical flow by the body. Most households in the United States are supplied with both 120V and 240V electrical outlets. Outlets supplied with 240V are reserved for larger appliances, such as clothes dryers or air conditioners. The majority of animal injuries are caused by 120V electrical currents, as these are generally the most common and accessible outlets in the home. Resistance of the body to electrical current also plays a major role in the severity of injury. Dry skin has a very high resistance to electrical flow, thereby allowing less energy to be transferred to the body. However, wet skin or moist mucous membranes (such as the oral cavity) have a low resistance to electrical energy, allowing a high flow of electricity to the tissues and subsequent increased damage.

Other factors that must be considered in determining the severity of injury are the type of current involved (AC [alternating current] versus DC [direct current]) and the duration of exposure. AC electricity, which is most common in US households, normally results in more severe injuries at the same amperage than DC electricity. Exposure to AC electricity normally elicits muscular contraction, thus impeding or preventing the animal from releasing the electrical source. Therefore, the exposure time to the electricity is generally much higher than that which occurs with DC, in which muscle tetany does not occur.

Damage that occurs from electrocution is mainly derived from two sources: heat generation and electroporation. In cases of high-voltage electrocution, the arcing of electricity from a nearby conductor to the animal's body may generate high-intensity heat. However, most thermal burns are a direct result of electricity passing through the animal's tissues. As electricity flows through tissue, the release of energy causes superheating of intracellular and extracellular fluid, resulting in steam production and necrosis of affected tissue. Damage to this tissue is also propagated by a phenomenon known as electroporation. As the electrical energy travels through tissue, electrical fields disrupt cellular membranes, thus causing osmotic damage to the surrounding cells. The severity of these resultant forces depends on the factors listed above.

DIAGNOSTIC CRITERIA

Historical Information

Gender Predisposition: None.

Age Predisposition: Pediatric or young animals are most commonly involved with electrical cord injuries because they are more likely to chew or play with the cords.

Breed Predisposition: None

Owner Observations: Owners may occasionally witness the incident but are more likely to find their pet in respiratory distress or unconscious near a source of electricity. Exposure to electricity may be evident by the presence of chew marks on a nearby cord or retention of the cord in the animal's mouth as a result of tetanic muscular contraction.

Other Historical Considerations/Predispositions: Winter holiday seasons tend to be the most common time of year for electrical injuries to occur, as many households are decorated with low-voltage lighting

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PREVENTING ELECTRICAL CORD INJURIES

- Electrical cords should be kept out of reach of animals in the home.
- During holiday seasons, animals should be kept out of areas with a large amount of decorations, and decorations should be unplugged from wall outlets when animals are unsupervised.
- Electric heating pads or lamps should be avoided with puppies or kittens. Not only are these items a shock hazard, they may also cause direct thermal burns. Water blankets are a much safer alternative.

(i.e., Halloween or Christmas decorations, Christmas trees) that is not normally present in the animal's environment. Also, the winter holidays are a major time of year when puppies or kittens are introduced into homes.

Physical Examination Findings

- **Thermal burns:** Although burns may be found at any point of contact, they are most commonly found in the oral cavity or commissures of the lips. The severity of these burns may range from mild hyperemia to full-thickness or third-degree burns.
- **Cardiac arrhythmias:** Severity and type of arrhythmia vary according to the intensity of electrical exposure. High-amperage current may result in asystole, which often may be converted with cardiopulmonary cerebral resuscitation (CPCR). Lower-amperage current, like that in most household exposures, commonly results in ventricular dysrhythmia or fibrillation. Most presenting animals are tachycardic, although some patients may develop bradycardia as a result of decompensatory shock or hyperkalemia.
- **Respiratory distress:** Patients may exhibit apnea, tachypnea, and/or cyanosis. These signs may be a result of neurogenic pulmonary edema, facial or nasopharyngeal edema, or tetanic contraction of the diaphragmatic musculature. Harsh lung sounds or crackles are commonly heard on auscultation. If pulmonary edema occurs, it normally develops within the first few minutes after the electrical shock but may continue to progress over the first 12 to 24 hours.
- **Neurologic disorders:** Impaired consciousness, focal muscular tremors, seizures, paresis, or paralysis may be present.
- **Pain.**
- **Alterations in blood pressure:** Hypertension may be present in patients secondary to pain and/or hyperdynamic shock; the latter may progress to hypovolemic shock and subsequent hypotension.
- **Hyperthermia.**

Laboratory Findings

- Routine **complete blood counts** and **serum chemistries** are usually within normal limits.
- **Hypoxia** (partial pressure of arterial oxygen, < 90 mm Hg) and/or respiratory acidosis (partial pressure of arterial carbon dioxide, > 40 mm Hg) may occur with development of neurogenic pulmonary edema.
- **Hyperkalemia** may occur secondary to tissue necrosis and rhabdomyolysis.
- **Myoglobinemia** and/or **myoglobinuria**.
- **Hemoglobinemia** and/or **hemoglobinuria**.
- **Hypoproteinemia** may occur in patients with severe burns.

Other Diagnostic Findings

- **Electrocardiogram (ECG):** Such abnormalities as sinus tachycardia, ventricular arrhythmias or fibrillation, or heart conduction blockade may be present.
- **Thoracic radiography:** May reveal alveolar consolidation, consistent with neurogenic pulmonary edema. This consolidation normally initiates in the caudodorsal lung fields but may progress to other lung lobes.
- **Skull and/or dental radiography:** Damage or fractures to teeth and/or mandible may be evident. These may be the result of direct electrical burns or trauma related to tetanic contracture of the masticatory muscles.
- **Abdominal radiography and ultrasonography:** May reveal the presence of generalized intestinal ileus secondary to electrical dysrhythmia.

Summary of Diagnostic Criteria

- Diagnosis may be confirmed with owner observation of electrocution.
- Presence of oral thermal burns may be suggestive but is not diagnostic.
- Neurogenic pulmonary edema in a young animal is also supportive of electrical cord injury.

Differential Diagnosis

- **Oral cavity lesions secondary to electrical burns:**
  - — Chemical burns.
  - — Nonelectrical direct-heat burns.
  - — Flame burns.
- **Pulmonary edema:**
  - — Seizures.
  - — Head trauma.
  - — Upper airway obstruction.

— Inhaled toxins.
— Drug toxicity.
— Smoke inhalation.
— Near-drowning.
— Pulmonary contusions (trauma).
— Pneumonia.
— Congenital heart disease with congestive failure.

TREATMENT RECOMMENDATIONS

Initial Treatment—At Time of Electrical Cord Exposure

- Source of electricity should be shut off, preferably at the electrical panel although the cord may be unplugged from the outlet if conditions permit.
- Owner or observer should be warned against touching the animal while electricity is still on, as contact could result in spread of the electrical current and electrocution of the person trying to render aid.
- If the patient is not breathing or is in asystole, CPCR should be started by the owner as quickly as possible.

Initial Treatment—In the Emergency Clinic

- Patient's cardiovascular and respiratory status should be evaluated quickly.
- If no heartbeat is auscultated, CPCR should be initiated immediately.
- If the patient is unconscious or in respiratory distress, the airway should be evaluated for patency and supplemental oxygen should be provided. Intubation of the patient should be considered if excessive pharyngeal edema or cyanosis is present.
- Correction of hypovolemic shock should also be initiated. Crystalloids should be used cautiously if pulmonary edema is suspected or present. If possible, the initial bolus should not exceed 20 ml/kg. Colloidal support may be a more appropriate choice to help correct hypovolemic shock in these cases. Hetastarch can be administered in increments of 5 ml/kg up to 20 ml/kg until pulse quality and blood pressure improve.

Alternative/Optional Treatments/Therapy

- Furosemide: 1 to 2 mg/kg IV q6–8h as needed to reduce pulmonary edema. Although this may be beneficial, the use of this medication is controversial. Further discussion is located in the Checkpoints section. **$**
- Positive-pressure mechanical ventilation may be required for patients with severe respiratory distress unresponsive to oxygen supplementation. **$$–$$$**

CHECKPOINTS

- Pulmonary edema resulting from electrocution is classified as neurogenic pulmonary edema. The true pathophysiology is currently unknown, but it is believed to be a result of direct vascular barotrauma. Exaggerated increases in sympathetic tone during electrocution (and other pathologic events, such as seizures and head trauma) result in severe vasoconstriction of the pulmonary vasculature. This vasoconstriction produces a substantial increase in pulmonary hydrostatic pressure. Pulmonary edema then forms as a direct result of extravasation of fluid into the alveoli and from hypertension-induced vascular endothelial damage.
- Benefit from the use of diuretics, such as furosemide, is controversial in patients with neurogenic pulmonary edema. Although pulmonary edema may develop during the initial event, no true fluid volume overload or prolonged pulmonary hypertension occurs. Therefore, the use of diuretics may actually potentiate hypovolemia. This is especially true in patients with severe endothelial damage because increased vascular permeability leads to protein and fluid losses into the alveoli. In most cases, however, furosemide has proven to be beneficial. Although its major mechanism of action occurs at the ascending loop of Henle, furosemide has also been found to have a direct effect on the alveoli. It is believed that furosemide acts on alveolar cells, causing an active pumping of fluid from the airspaces. Therefore, its benefit on pulmonary edema is also direct, not simply a reduction in systemic fluid volume and hydrostatic pressure.

- Bronchodilators may also be of benefit with respiratory distress:
  — Terbutaline: 0.01 mg/kg SC q6–8h. **$**
  — Aminophylline: 6–11 mg/kg IV q8h. **$**
  — Albuterol: 0.02–0.05 mg/kg PO q12h. **$**
- Colloidal support (hetastarch, plasma, 10% human albumin) may be useful in cases of severe burns, in which hypoproteinemia may be a complication.
  — Hetastarch: 20 ml/kg/day IV as a constant-rate infusion. **$**
  — 10% Human albumin: 1.5 ml/kg/day IV as a constant-rate infusion over 4–6 hours. **$**
  — Plasma: 20–30 ml/kg/day IV as a constant-rate infusion over 4–6 hours. **$**

- Antiarrythmogenics: Rarely needed in electrical injury but may be required in patients with severe arrhythmias. **$**
- Antiseizure medication: Midazolam or diazepam (0.5 mg/kg IV or rectally) as needed to control seizures. **$**

Supportive Treatment

- **Supplemental oxygen** should be implemented in cases of respiratory distress from pulmonary edema. Nasal oxygen or oxygen-cage therapy normally provides an oxygen concentration of 40%. However, if the patient remains in distress or blood gas values continue to remain unacceptable (partial pressure of arterial oxygen, < 60 mm Hg or partial pressure of arterial carbon dioxide, > 60 mm Hg), nasotracheal oxygen or intubation with mechanical ventilatory support should be considered. **$$–$$$**
- **Antibiotics** may be necessary, especially with extensive thermal burns. Broad-spectrum antibiotic therapy should be considered. Anaerobic coverage is very important with full-thickness or extensive oral lesions. **$**
- **Pain control** is also warranted for patients with thermal burns. Opioids are generally the drugs of choice. However, combination drug therapy may be beneficial in patients with severe burns. In dehydrated animals, NSAIDs or glucocorticoids should be avoided or used with extreme caution.
  - — Hydromorphone: 0.08–0.2 mg/kg IM, IV, or SC q2–6h. **$**
  - — Fentanyl: 5 µg/kg bolus IV followed by 5–10 µg/kg/hr IV as a constant-rate infusion. **$**
  - — Buprenorphine: 0.005–0.02 mg/kg IM, IV, or SC q6–12h. **$**
- **Wound care** must also be provided. The topic of burn wound management is beyond the scope of this article, although a few points should be considered. Application of chilled sterile saline or cool compresses to burn wounds within 2 hours of the injury helps decrease residual heat, thereby reducing the overall area of tissue destruction. However, the patient must be continuously monitored to prevent development of hypothermia. Topical antibiotics should be applied to the wounds to aid in prevention of bacterial contamination. **$–$$**
- **Nutritional support** is also critical in patients with extensive burns. To heal adequately, animals with large burn wounds require approximately two to three times their normal caloric needs. For inappetent patients or those with oral burns, other means of delivering nutrients (e.g., nasoesophageal or esophagostomy tubes) should be considered. **$–$$**

Patient Monitoring

- Blood gas values and pulse oximetry should be monitored closely over the first 24 to 48 hours to ensure adequate tissue oxygenation and pulmonary function.
- Serial ECGs or telemetry should be performed to monitor for arrhythmias.
- Thoracic radiographs should be taken at presentation and every 24 hours thereafter to monitor pulmonary edema.
- Renal values (blood urea nitrogen, creatinine, urine specific gravity, and urine output) should be monitored to evaluate adequate hydration. Patients should also be monitored for pigmenturia (hemoglobinuria, myoglobinuria) as diuresis may be required to prevent renal tubular toxicity in the face of massive tissue damage.
- Creatine kinase and serum potassium levels should be evaluated to monitor for hyperkalemia if extensive muscle damage has occurred from thermal burns.
- Colloidal oncotic pressure, albumin, and total serum protein should also be monitored in patients with large areas of skin necrosis because large amounts of protein are lost in denuded areas.

Home Management

Home monitoring of patients with electrocution or electrical cord injury is quite variable depending on the type and location of the injury.

Milestones/Recovery Time Frames

- With proper therapy, pulmonary edema usually subsides within 72 hours.
- Recovery time for thermal burns is quite variable, depending on the size and location of the injuries.

Treatment Contraindications

- Overzealous crystalloid administration should be avoided because it may potentiate pulmonary edema. Colloids may be a better choice in patients with pulmonary edema.
- Use of corticosteroids is controversial in the therapy of hypovolemic shock and may increase the risk of infection, especially with burn wounds.

PROGNOSIS

Favorable Criteria

- Low-amperage electrocution.
- Low total body surface area of wounds.

- Thermal burns affecting only the epidermis.
- Lack of pulmonary edema or resolution of edema within first 24 hours.

Unfavorable Criteria

- Continued respiratory distress with supplemental oxygen and/or requirement of positive-pressure mechanical ventilation.
- Thermal burns covering more than 50% of total body surface area.
- Development of uncontrollable cardiac arrhythmias.
- Continued seizure activity despite therapy.

RECOMMENDED READING

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