An Electrical Burn

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From the Case Records of the Alpert Medical School of Brown University Residency in Emergency Medicine

DR. SETH GEMME: Today's case is a 19-year-old woman with no past medical history who presented after she received a significant electrical injury while reaching into a cabinet in an abandoned power sub-station. Her companion stated that when she reached into the cabinet she grabbed onto a "green glass object." He heard a screeching sound and the patient was thrown to the floor. Her hand was severely burned and she was confused. When EMS arrived clean dressings were immediately applied to her burns. She denied drug or alcohol use and reported severe pain in her left arm and right leg.

DR. KEN WILLIAMS: What immediate life-threatening conditions must be recognized and treated by the pre-hospital health care providers? Where should the patient be transported?

DR. GEMME: The first objective of the EMS providers in an emergency response is scene safety. The responders must confirm that the power company has turned off power, and that objects around the victim will not produce or conduct electricity. Once scene safety is confirmed, airway, breathing and circulation must be addressed. Life-threatening arrhythmias should be treated according to advanced cardiac life support protocol. IV access should be obtained and a fluid bolus given. If blunt trauma is suspected, as in this case in which she was thrown to the ground, spine immobilization precautions must be completed. The patient's burns should be kept clean with appropriate sterile dressings. The patient should be transported on a cardiac monitor by advanced level EMS to a level 1 trauma center. The patient requires medical and, most likely, surgical management by physicians who are experts in burn care. Patients who require transfer to a burn center include any who have partial thickness burns >10% of total body surface area, burns to the face, hands, feet, genitalia, perineum, major joints, any third-degree burn, chemical burns, electrical burns, inhalation injury, and burns with multiple injuries. Although only needing to meet one to qualify for transfer, our patient meets many of these criteria.

DR. SETH ROUGAS: What did the physical exam reveal?

DR. GEMME: On primary survey the patient's airway was patent, her breath sounds were equal and she had a BP of 114/86 mm Hg with a regular heart rate of 104. She was in mild distress due to her pain, but cooperative with the exam. She was alert and oriented to person only and with a Glasgow Coma Scale (GCS) of 14 (she lost one point for confused speech). She moved all limbs and had severe burns to her left hand, left arm and right knee. Her secondary survey examination revealed a normal HEENT exam. EMS placed the patient in a cervical spine collar but she was without tenderness on palpation. Her chest, abdomen and pelvis were normal. Her left arm had partial deep (second-degree) burns to the antecubital fossa and severe full thickness (third-degree) burns over all aspects of her left hand. Her hand was held in a flexed and rigid position due to tetany and spasm. Her right knee had second-degree burns on the medial aspect. Her left forearm and upper arm had tight compartments without palpable pulses distally. Her legs had normal compartments to palpation and intact pulses. EMS reported that she was shocked by 10,000 V of electricity.

DR. WILLIAM BINDER: How often do electrical injuries occur and what is the significance of the amount of voltage?

DR. GREGORY JAY: Data from the 1990s suggest that about 1,000 people in the United States die annually due to electricity exposure.[1] There is a bimodal distribution of injury, with one peak prior to age 6, and another occurring among young adults.[2, 3] Males are predominantly affected.[4, 5] While some evidence suggests that the incidence of low-voltage injury has slowed in the pediatric population, high-voltage injury in the adult population has remained unchanged, and electrocution is the fourth leading cause of death among work-related traumatic injury cases.[4, 6]

A high-voltage injury has been historically defined as exposure to 1,000 volts or more. This number is somewhat arbitrary as significant injuries have occurred at 600 V from 3rd rail injury.[7] Voltage is often the only variable known, and higher voltage can lead to significant burns. (Ohm's law, $V = I \times R$, readily translates to tissue damage due to Joule's law, in which thermal energy = $I^2 \times R \times T$, where I is current, R is resistance and T is time of exposure.) Current, on the other hand, has the greatest impact on energy delivered, as is evidenced by Joule's law, and can be either direct or alternating.

Household electricity is typically 110–230 V and is alternating current. A TASER can deliver 50,000 volts over milliseconds, while high tension power lines can deliver 100,000 volts, and lightning can deliver over 10 million volts of direct current.[8, 9] Direct current causes a single muscle contraction and can lead to mechanical injury as the patient can be literally thrown from the source of electricity. Alternating current presents different dangers as it can cause repetitive muscle contractions creating tetany in a hand grip leading to prolonged exposure to a source of electricity.[1] Mechanisms of injury due to electricity can be from direct impact of current on nerve conduction systems leading to arrhythmias, blunt mechanical injury, thermal energy injury causing significant burns, and electroporation, in which cell membranes are rendered porous leading to cell death.[1]

DR. RACHEL FOWLER: What are the clinical implications of an electrical injury?

DR. GEMME: Injuries to each organ system occur due to electrical exposure. Cardiac injury can occur from coronary artery spasm, cell death through electroporolation, as well as arrhythmia. Ventricular fibrillation can occur with low voltage alternating current, while asystole is more common with direct current or high voltage alternating current.[1, 10, 11, 12] Respiratory arrest may occur due to inhibition of CNS respiratory drive or through paralysis and tetany of respiratory muscles.[1] The musculoskeletal system can be affected by the high resistance of bone and can consequently suffer severe electrothermal injury. Additionally, muscle tetany can lead to falls and fractures of the long bones.[1] Muscle is subject to edema and deep tissue necrosis leading to rhabdomyolysis and compartment syndromes.[13] Neurologic abnormalities are quite common in lightning and electrical injuries and cause a broad array of deficits. Sequelae extending from PTSD to post- concussive syndromes causing behavioral and personality changes can occur. In severe cases motor neuron syndromes, parkinsonism and dystonia have been reported.[14]

Burn injuries to skin can be due to current flow against tissue resistance leading to energy transfer and the heating of tissue. The burns suffered from these injuries are difficult to assess as the superficial manifestations belie deep tissue necrosis and damage.[13] Alternatively, burns can be due to the heat of arcing when high voltage current passes through the air – electricity can arc at temperatures of 4,000 degrees centigrade – or from materials being ignited.[15]

DR. THOMAS HARONIAN: Given her history of exposure and her injuries what type of electrical injury do you suspect and what diagnostic tests need to be preformed?

DR. GEMME: The patient likely sustained a high-voltage injury (>1,000 Volts). The point of contact was her left hand but the path of current flow is difficult to determine and is, at best, a clinical guess. Given the high-voltage injury, I was concerned for indirect blunt trauma, deep burns, tissue ischemia/necrosis, rhabdomyolysis, fracture, and the possibility of delayed sequel. Laboratory studies including a complete blood count, a basic metabolic panel (BMP), CPK, urinalysis, pregnancy test, and coagulation studies, as well as an ECG, and plain film radiographs of her chest, left hand, and right knee were obtained. Additionally, a brain and cervical spine CT were included and she was placed on a cardiac monitor. Finally she was started on intravenous normal saline and given a tetanus booster vaccine.

The patient's ECG demonstrated sinus tachycardia at a rate of 108 with normal intervals and no ischemia. Her chest x-ray and brain and cervical spine CT was unremarkable while the x-ray of her hand showed a severely contracted hand with diffuse soft-tissue edema and disruption. Her labs showed a slightly elevated WBC count at 15,000 wbcs/microliter, but electrolytes, urinalysis, ucg, and coagulation studies were normal. Her CPK was elevated at 1050 U/L.

DR. BRIAN CLYNE: Given her trauma evaluation, what was your treatment and ultimate disposition plan for the patient?

DR. GEMME: The patient's left hand was severely burned and the circumferential nature of the burns made it quite likely that she would suffer compartment syndrome in both her left arm and left forearm. Consequently, the patient went to the operating room from the ED and required left hand amputation due to the extent of necrotic and unsalvageable tissue. She was treated with left arm and forearm fasciotomies and admitted to the trauma intensive care unit for post-operative management and right leg compartment checks. She required several revisions of her left arm surgery and closure of her fasciotomies at later dates. While high voltage injury can result in the development of cataracts within hours to many months after an incident, it is usually the result of electrical exposure to the face.[16] The patient demonstrated no evidence of cataract on immediate and delayed ophthalmology evaluation, and follow-up was recommended as needed for any perceived changes in visual acuity. The patient did, however, experience severe depression due both to the amputation and from the neuropsychiatric effects of high-voltage electrical exposure. She was discharged several weeks after her presentation.

FINAL DIAGNOSIS: Severe burns and amputation of left hand due to electrical injury; depression.

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