A shocking episode

Care of electrical injuries

Robert Primavesi MD CM FCFP(EM)

While making a speedy getaway from her new husband who tried to strangle her, Edie Britt, Nicollette Sheridan's character on the ABC television program Desperate Housewives, *crashed her car into a telephone pole on Wisteria Lane. When Edie stepped out of the car and onto the wet road, the pole's downed live wire instantly electrocuted her. Why did Edie die?*

Besides the curious absence of anyone in the neighbourhood trained or willing to initiate bystander cardiopulmonary resuscitation, Edie likely died of ventricular fibrillation, the most common arrhythmia resulting from electrical injury. Patients who present in cardiac arrest after electrical injury should have lethal arrhythmias treated according to standard advanced cardiac life support algorithms.

Edie is an unlikely victim of an electrical injury that is most common among electricians or construction workers who work with or around electricity and risk-taking teenagers who climb fences surrounding transformer stations. Just as in Edie's case of hitting the utility pole, mechanical trauma is frequently associated with electrical injury. A patient suffering from an electrical injury should first be considered as a trauma victim—the initial assessment should follow the advanced trauma life support guidelines for the identification and treatment of serious life-threatening injuries.

Shock value

If Edie had been taking a bath and had accidentally dropped a hair dryer into the water-filled bathtub, would the outcome have been the same?

The result of this scenario would most definitely be fatal. The most obvious difference between electrocution by a high-tension wire and electrocution by household current is the voltage itself. High or low voltage is arbitrarily defined as greater or less than 1000 V. However, voltage is only one of the factors that determine the outcome of electrical injury.

Current is the most important determinant of tissue damage. In most cases the voltage is known but the actual current cannot be determined. In general, higher voltage produces larger currents. As current moves through tissues, the electrical energy produces heat that causes tissue injury. If the voltage is high enough, current will flow through even the most resistant tissues.

Skin resistance is the most important factor in impeding current flow and protects against electrical injury; however, resistance changes with skin thickness and moisture. This explains fatal low-voltage household electrocutions or bathtub-related electrical deaths (or electrocution by stepping out of a car and into an electrically charged puddle).

Given the option, current will always flow along the path of least resistance. The most severe tissue damage occurs at the entrance and exit points where current is concentrated and reconcentrated. Entry and exit burns signify substantial current flow and represent an increased risk of deep tissue damage. The extent of deep tissue damage is not apparent from the surface appearance of the wound and must be regarded with a high degree of suspicion and trepidation. In practice, high-voltage injuries are more likely to be associated with deep tissue injury, while tissue necrosis is unlikely with household electrical currents (ie, 120 to 240 V).

Surviving electrical injury

If Edie had survived … How long would she stay in hospital? What sequelae might she suffer from? What if she were pregnant?

The notion that Edie might survive her electrocution is not unrealistic television fantasy. History shows New York's first victim of the electric chair in 1890, convicted murderer William Kemmler, did not die the first time the switch was pulled, demonstrating that a momentary dose of high-voltage electricity is not necessarily fatal. A second attempt was initiated immediately; the current remained on until he was in flames.

While ventricular fibrillation is the most common cause of death following both high- and low-voltage electrical injuries, survivors can demonstrate many arrhythmias, from premature ventricular contraction to atrial fibrillation. Myocardial damage is uncommon. An electrocardiogram (ECG) does not show standard patterns of ischemia because injury is predominantly epicardial rather than transmural and does not follow the coronary vessels. Measurement of cardiac markers for the purpose of cardiac evaluation is not warranted for household electrical injuries. An elevated creatine kinase level is a more useful sign of extensive burns than of myocardial damage.

Several authors recommend cardiac monitoring for as long as 24 hours after electrical injuries to prevent deaths from delayed arrhythmias.[1,2] However, arrhythmias in monitored patients after electric shock

are uncommon and if present are documented on the first ECG. Based on the information available in the literature, cardiac monitoring is not justified in asymptomatic patients or in patients with only cutaneous thermal burns who have normal ECG results after 120- or 240-V injuries.[3-7] These patients can be safely discharged.

Neurological injury is a frequent complication of high-voltage injuries. Acute central nervous system injury might manifest as respiratory arrest as a result of paralysis of the central respiratory centres, amnesia, altered mental status, seizures, coma, quadriplegia, or localized motor paresis. Delayed central nervous system effects include ascending paralysis, transverse myelitis, and amyotrophic lateral sclerosis.

High-voltage electricity causes serious vascular injury. Vein thrombosis and tissue swelling occur from capillary damage. Ongoing inflow through the artery into an extremity without sufficient outflow results in compartment syndrome. If there is substantial muscle damage, myoglobinuria might cause acute renal failure.

Cataracts are associated with electrical injuries to the head and shoulders. Signs of lens cloudiness can be seen as early as 4 to 6 months postinjury. Ophthalmology referral and long-term follow-up is necessary for all patients with high-voltage injuries to the upper chest, neck, or head.

As with extensive thermal burns, infection is a common cause of death following initial resuscitation. There is a special risk for clostridial infections (gas gangrene and tetanus). Early debridement and tetanus prophylaxis in the emergency department might minimize the risk of infection.

For pregnant patients, electrical impulses might pass through the mother and the fetus. High-voltage injuries have been associated with intrauterine growth retardation, fetal distress, and fetal death. Fetal monitoring is essential for pregnant patients.

The consequences for the survivors of electrical injuries are myriad. There is no centre of expertise in Canada for individuals who have sustained an electrical injury. It is difficult for health care providers to develop and maintain expertise owing to the relatively low incidence and prevalence of electrical injuries. To this end, Ontario's Hydro One has funded a Chair in Electrical Injury through the Sunnybrook Foundation.

BOTTOM LINE

- Mechanical trauma is frequently associated with a high-voltage electrical injury; initial assessment should follow advanced trauma life support guidelines for the identification and treatment of serious life-threatening injuries.
- Entry and exit burns signify substantial current flow and represent an increased risk of deep tissue damage; the extent of deep tissue damage is not apparent from the surface appearance of the wound.
- Patients who present in cardiac arrest after electrical injuries should have lethal arrhythmias treated according to standard advanced cardiac life support algorithms.
- Cardiac monitoring is not justified in patients with household current injuries who have normal ECG results and who are asymptomatic or have only cutaneous thermal burns. These patients can be safely discharged.

POINTS SAILLANTS

- Des traumatismes mécaniques sont souvent associés aux blessures causées par un fort voltage électrique; après avoir appliqué la technique avancée de maintien des fonctions vitales des grands blessés, il faut procéder à une évaluation initiale pour identifier et traiter les blessures graves mettant la vie en danger.
- Des brûlures aux points d'entrée et de sortie signifient le passage d'un courant électrique substantiel et représentent un risque accru de dommages aux tissus profonds; l'ampleur des dommages aux tissus profonds n'est pas apparente dans les blessures à la surface.
- Il convient de traiter l'arythmie létale des patients en arrêt cardiaque par suite d'une blessure électrique conformément aux algorithmes de la technique avancée de maintien des fonctions vitales des grands blessés.
- Le monitorage cardiaque n'est pas justifié chez les patients ayant subi une blessure domestique courante dont l'ECG est normal et qui n'ont pas de symptômes ou qui n'ont que des brûlures thermiques cutanées. Ces patients peuvent recevoir leur congé sans risque.

TASER discussion

If police used a TASER electronic device to restrain a hostile Edie after a high-speed chase, what kind of electrical shock would she experience?

I cannot discuss electrical injuries without commenting on TASER electronic control devices. *TASER* is an acronym for Thomas A. Swift's Electric Rifle, named after young genius inventor Tom Swift—a fictional character from a series of children's science-fiction novels written in the early 20th century. A TASER is a conducted energy device or stun gun, which is intended to be a nonlethal alternative to firearms for police.

Compressed nitrogen propels 2 darts linked back to the TASER by insulated wires. The darts can travel more than 11 m and can penetrate up to 4 cm of clothing. A 5-seconds-long shock of 50 000 V is administered to the suspect. The electrical pulse is delivered at a high voltage because the electric current has to pass through

clothing and air—neither are good conductors of electricity—to make a complete circuit with the suspect's skin. The actual voltage delivered and the effective current are much smaller.[6-8] Police can administer subsequent doses of electricity if the suspect is not subdued the first time.

Coroners have invoked the term *excited delirium* to explain why someone dies after a TASER incident. Excited delirium is a controversial condition used to explain deaths of individuals in police custody, in which the person being arrested or restrained shows some combination of agitation, violent or bizarre behaviour, insensitivity to pain, elevated body temperature, or increased strength. Such episodes of excited delirium can also happen to psychiatric patients and people using stimulant drugs (eg, cocaine), and can result in an irregular heartbeat and sudden death.

Further reading and resources

For physicians

- Koumbourlis AC. electrical injuries. *Crit Care Med* 2002;30(11 Suppl):S424-30.
- Spies C, Trohman RG. Narrative review: electrocution and life-threatening electrical injuries. *Ann Intern Med* 2006;145(7):531-7.
- Electrical Safety Programs Solutions Inc [website]. *Hydro One Chair in Electrical Injury*. Toronto, ON: Sunnybrook Foundation; 2009. Available from: **www.esps.ca/Default.aspx?cid=239&lang=1**.

For patients

- Hydro-Quebec [website]. *What to do in case of electric shock*. Montreal, QC: Hydro-Quebec; 2009. Available from: **www.hydroquebec.com/security/que_faire_choc.html**.
- Hydro One Networks Inc [website]. *Electrical safety*. Toronto, ON: Hydro One Networks Inc; 2008. Available from: **www.hydroonenetworks.com/en/safety/**.

Dr Primavesi is an emergency physician at the McGill University Health Centre in Montreal, Que.

Competing interests
None declared

References

1. Alexander L. Electrical injuries of the nervous system. *J Nerv Ment Dis* 1941;94:624-32.
2. Jensen PJ, Thomsen PE, Bagger JP, Nørgaard A, Baandrup U. Electrical injury causing arrhythmias. *Br Heart J* 1987;57(3):279-83.
3. Bailey B, Gaudreault P, Thivierge RL, Turgeon JP. Cardiac monitoring of children with household electrical injuries. *Ann Emerg Med* 1995;25(5):612-7.
4. Blackwell N, Hayllar J. A three year prospective audit of 212 presentations to the emergency department after electrical injury with a management protocol. *Postgrad Med J* 2002;78(919):283-5.
5. Chen EH, Sareen A. Do children require ECG evaluation and inpatient telemetry after household electrical exposures? *Ann Emerg Med* 2007;49(1):64-7.
6. Cunningham PA. The need for cardiac monitoring after electrical injury. *Med J Aust* 1991;154(11):765-6.
7. Fatovich DM, Lee KY. Household electrical shocks: who should be monitored. *Med J Aust* 1991;155(5):301-3.
8. Vilke GM, Sloane CM, Bouton KD, Kolkhorst FW, Levine SD, Neuman TS, et al. Physiological effects of a conducted electrical weapon on human subjects. *Ann Emerg Med* 2007;50(5):569-75. Epub 2007 Aug 24.

Emergency Files is a quarterly series in *Canadian Family Physician* coordinated by the members of the Emergency Medicine Committee of the College of Family Physicians of Canada. The series explores common situations experienced by family physicians doing emergency medicine as part of their primary care practice. Please send any ideas for future articles to **Dr Robert Primavesi**, Emergency Files Coordinator, at **robert.primavesi@muhc.mcgill.ca**.