CLINICAL UPDATES

Electrical injury

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Electrical injuries can range from small skin burns to life threatening internal organ damage. The most extreme form of electric shock, such as caused by a lightning strike, often results in instant death by electrocution. There is a lack of evidence regarding the management of patients after electrical accidents, which can cause concern for clinicians when these patients present.

This article discusses the main types of electrical injuries, their underlying pathophysiology, and practical issues relating to monitoring and treating seriously injured patients as well as those who are apparently well.

How common are electric shocks?

Many electrical accidents go unreported, so the true incidence is difficult to estimate. In the United States, the American Burn Association (www.ameriburn.org) estimates 4400 people are injured in electrical accidents and 400 others die from electrocutions each year, which are mostly work related (miners, electricians, and construction workers). Lightning strikes are responsible for up to 100 deaths a year.

Of those admitted to US specialist burn units annually, 3-6% have had an electric shock. Many of the victims are young adults or adolescents, whose injuries often result from outdoor adventurous activities (such as climbing an electric pole, exploration of dangerous place as railway stations) and children involved in household accidents, mostly due to oral contact with electrical cords or cord sockets, contact with wall sockets directly (“finger in the socket”), or via a conducting foreign object (metal keys, pins, or cutlery).

How is the body affected after an electric shock?

Physiology

Electrical injuries affect the body in various ways. There are direct effects of current on body cells: for example, electric current can affect cell membranes, abruptly altering their electrical properties (cellular depolarisation) and causing direct cell injury by forming pores in cell membranes (electroporation).

Electric current also causes thermal injury due to conversion of electricity into heat as current passes through body tissues. Cellular and thermal injuries can be exacerbated by trauma sustained at the same time, such as a fall.
What you need to know

- Electrical injuries are relatively uncommon but can be life threatening, causing extensive burns or internal organ damage
- Wet skin can make otherwise be a minor injury more serious
- Arrhythmias are the most common cardiac complication and may sometimes present late
- Non-specific electrocardiographic (ECG) changes may be the only indicator of cardiac damage
- Patients who have a normal ECG on admission after a low voltage injury with no loss of consciousness or initial cardiac arrest may be discharged home

Box 1: What is an electric shock?

- Electricity is a flow of electrons, measured in amperes (I), across a potential gradient from high to low concentration, expressed in voltage (V)
- Ohm’s law (I = V/R) expresses the relation among voltage (V), current (I), and the impedance to electrical flow or resistance (R in ohms)
- Joule’s law (W (Joules) = R × I² × T) gives the heat energy produced as a result of current flow

Box 2: Main factors that determine the nature and severity of electrical trauma

- Voltage (see box 3)
- Resistance to current flow through the body
- Type of current source (direct or alternating current)
- Duration of contact with the current source
- Path taken by the current through the body

Box 3: Main sources of electrical current, with associated voltage

High voltage
- High voltage lines (45 000 to 400 000 V)
- Rail network lines (25 000 V)
- Overhead lines (1500 V)

Low voltage
- Mines (960 V)
- Subway electric rails (750 V)
- Workshops (380 V)
- Domestic supplies (US 110 V, Europe 220 V)

Effects on specific organ systems

Figure 3 summarises the main types of organ-specific injuries after an electric shock. Cardiac effects are the most serious and among the most common electrical injuries. The heart is more commonly affected than other internal organs because electric current usually follows the path of lowest resistance in the body along blood vessels and nerves, directing the current towards the heart. Its central anatomical location in the chest also places it in harm’s way from currents passing both horizontally (hand to hand) and vertically (head to foot or hand to foot). Cardiac tissue vulnerability to potentially lethal arrhythmias when exposed to an external electric field sets it apart from other organs.

How do I manage my patient after an electric shock?

The infographic suggests an approach to the assessment and management of electric shock based on currently available literature.

The first step is to turn off the current source to prevent a further accident. Then, the management is mainly symptomatic. In witnessed accidents, a prompt and sometimes prolonged resuscitation attempt is warranted. Immediate resuscitation of patients in cardiac arrest from electrocution can result in long term survival, and complete recovery has been reported even after prolonged life support. Manage patients according to standard life support principles. Even when low blood pressure is not present, intravenous hydration is usually desirable to prevent kidney shut down. Adjust other aspects of management according the nature and severity of the injuries.

Discharge

Although only small studies have addressed this, all suggest that, in cases of low voltage injuries without any loss of consciousness or initial cardiac arrest, occurrence of serious arrhythmia is unlikely when electrocardiography at hospital admission is normal. Similar results have been reported with high voltage injuries, but more evidence is needed to support the safe discharge of these patients home. There are no established standards for the duration of monitoring after an electric shock, but 24 hours after admission or after resolution of arrhythmias is the most commonly adopted approach. There is little data on the potential risks to an unborn baby after electrical shock to the mother during pregnancy, but it is recommended that both mother and fetus are monitored in hospital.
In children no major differences in injury type or prognosis have been reported compared with adults, and so current guidelines on cardiac monitoring are the same.\textsuperscript{24}

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What to say to patients

• If there is no substantial injury or electrocardiographic abnormality, reassure the patient that there is a low likelihood of any serious effect on his or her health
• In the case of asymptomatic patients with non-specific electrocardiographic changes, explain that there is a need for a period of observation because of the occasional risk of delayed cardiac arrhythmias (which can rarely lead to sudden death). This involves electrocardiographic monitoring for at least 24 hours
• In all patients, provide advice on prevention of future accidents

Education into practice

• Are you comfortable with the management of an apparently healthy patient after electric shock?
• Having read this article, what would you say to a patient with non-specific electrocardiographic changes after an electric shock who wants to be discharged home?

How patients were involved in the creation of this article

We obtained feedback on the article from three patients admitted to our hospital having had an electric shock. They provided input on whether the article was clear and gave information on the main risks and the right approach to adopt in situations involving electrical injury. Their suggestions to improve the article, such as to provide examples of electrical current sources with associated voltages, were then incorporated

Figures

![Diagram summarising main mechanisms of electrical current effects on cells and human body](http://www.bmj.com/permissions)
Fig 2 (A) Finger skin burns at entry and exit points of electrical current (courtesy of Dr Kras, Centre Hospitalier de Martigues, France). (B) Severe foot burn after an electrical accident.
CARDIAC

Arrhythmias
• The commonest complication, supraventricular arrhythmias (sinus tachycardic, atrial extrastyles, or atrial fibrillation) and ventricular arrhythmias (extrastyles, tachycardia, or fibrillation). Exposure to high voltage current is more likely to cause cardiac standstill (asystole), but even low voltage alternating current can cause cardiac arrest by ventricular fibrillation.
• There is a vulnerable period in every heart beat during which exposure to energy at a frequency of 50-60 Hz, used in most household and commercial electrical sources, can trigger fibrillation.
• Although most life threatening events occur immediately after electric shock, delayed ventricular arrhythmias have been reported up to 12 hours after the incident, with low as well as with high voltages.
• The mechanism behind electrically induced cardiac arrhythmias is hypothesised to be initial damage to heart muscle and subsequent scar formation leading to abnormal electrical activation of the heart.

Bradycardia
• Severe slowing of the heart rate can result from interference with the normal electrical (conduction) system, which can be delayed for months or years after the accident.
• The sino-atrial and atio-ventricular nodes responsible for impulse generation and propagation within the heart may be more susceptible to damage by electrical injury than other cardiac cells (neurotoxicity shows widespread areas of cell death, mainly in these electrical pathways).

Heart muscle injury
• May result from reduction of blood supply (ischaemia) or direct tissue death (necrosis)
• Chest pain may be absent, and injury may manifest only as non-specific electrocardiographic changes (Fig. 4). Increased levels of myocardial proteins in the blood (troponin I) from damaged tissue, or abnormalities such as altered contraction patterns on echocardiography or cardiac MRI.
• Occasionally, mostly after high voltage accidents, myocardial infarction can be caused by occlusion of coronary arteries by blood clots or spasm.
• Cardiac function usually returns to normal shortly after the event, but cardiac abnormalities sometimes persist.

RESPIRATORY ARREST
• Electric current, by interfering with usual transmission of nervous impulses, can paralyse the respiratory muscles (such as diaphragm) or cause them to seize up abruptly (tonic contraction).
• Inhibition of the centre controlling breathing in the brain.

SKIN BURNS
• Extensive burns can result in significant body fluid loss and infection, due to loss of skin barrier.

NEUROLOGICAL
• Damage to nerve tissue may cause loss of consciousness, impaired recall, spinal cord injury, paralysis, or loss of sensations in limbs.
• Neuropsychological problems are often underappreciated, but post-traumatic stress disorder, depression, and chronic neuropathic pain have been reported.

VASCULAR
• Clotting in blood vessels due to injury to vessel walls can compromise blood flow to organs.

KIDNEY FAILURE
• Myoglobin tubular precipitation caused by damaged muscles releasing myoglobin to the circulation and thus to the kidneys.

MUSCULOSKELETAL EFFECTS
• Bone fractures and luxations
• Direct muscle damage, rhabdomyolysis
• Compartment syndrome.

Fig 3 Main types of organ-specific injuries after an electric shock.
A 12-lead electrocardiogram and continuous Holter monitoring showing a huge transient QT interval prolongation (A) immediately after a high voltage electrical shock, associated with sinus tachycardia and premature ventricular extra beats (B) some hours later. The QT interval is the time between the start of the QRS complex and the end of the T wave. A lengthened QT interval indicates prolongation of electrical repolarisation, which can lead to ventricular arrhythmias. Corrected QT intervals (QTc) standards vary, but values greater than 460-480 ms are generally considered abnormal.
Electrical injuries caused by the action of an electric current on the human body can range from benign small skin burns to life-threatening internal organ damage. Most injuries are sustained through contact with low voltage domestic circuits, and will not need extensive treatment. However, cardiac monitoring is important in selected patients due to risk of cardiac arrhythmias.

**1 Early management**
- Turn off electrical source (if safe to do so)
- Perform basic life support if needed
- Immobilise head and neck (in severe injury)

**2 Clinical assessment**
- Check clinical signs to assess effects of the electrical current on the patient's body
- Extensive burns
- Pregnant women
- Loss of consciousness
- Determine path of current through body
  - Electricity usually flows from an electrical source, through the body to the ground. Locating entry and exit points can help to determine which organs could be damaged

**3 Discharge**
- If there is no cause for concern, consider prompt discharge

**Potential injuries**
- **Cardiovascular**
  - Arrhythmias (most common)
  - Heart muscle injury
  - Bradycardia
  - Clotting in blood vessels
- **Respiratory arrest**
  - Diaphragm paralysis
  - Tetanic contraction
  - Inhibition of control in brain
- **Skin burns**
  - Infection
  - Dehydration
- **Neurological**
  - Loss of consciousness
  - Impaired recall
  - Spinal cord injury
  - Paralysis
  - Loss of sensations in limbs
- **Kidney failure**
  - Myoglobin tubular precipitation
  - Generalized hypotension
- **Musculoskeletal**
  - Fractures/luxations
  - Muscle damage
  - Rhabdomyolysis
  - Compartment syndrome

**Determine voltage of accident**
- **Low voltage**
  - Mines
  - Subway rails
  - Workshops
  - Domestic
  - ECG anomaly
  - Arrhythmias
  - Troponin rise
- **High voltage**
  - High voltage line
  - Rail network
  - Overhead line
  - ECG and blood tests
  - Echocardiography
  - Cardiac MRI
  - Coronary angiography

**Admit to burns unit**
- Specialised surgical care, such as skin grafts

**Admit to obstetrics**
- Fetal cardiac monitoring

**Admit to hospital**
- Patients with initial loss of consciousness, cardiac anomalies, or high-voltage injury require continuous ECG monitoring
- Manage organ failure
- Monitor ECG for at least 24 hours
- Echocardiography
  - With or without:
    - Cardiac MRI
    - Coronary angiography
  - Depending on clinical findings
  - Explain to patient the occasional risk of delayed cardiac arrhythmias (which can very rarely lead to sudden death)

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