Microampere Electrocution during Haemodialysis—An Unrecognised Cause of Sudden Death

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Summary

A case of electrocution during haemodialysis is reported. Danger of microampere electrocution via artificial kidneys is emphasized. Prophylactic measures are recommended.

Introduction

Medicine has become more and more sophisticated with the introduction of modern technical equipment, which has invaded hospitals and medical centres to improve medical care. However, medical teams are not sufficiently trained in electrical safety precautions and hospitals are not prepared to instal and maintain every electromedical device (Bruner, 1970; Walter, 1970).

Lack of adequate official inspection of this type of equipment before sale transfers responsibility for safety and effectiveness to the user. Nobody really knows how many patients are electrocuted during diagnostic or therapeutic procedures (Burchell, 1967), but cases of electrocution with ECG apparatus (Moulopoulos et al, 1964; Noordjik, 1961), cardiac monitors (Nashat and Yassin, 1960), intracardiac pacemakers (Furman et al, 1961; Pengelly and Klassen, 1961; Graystone and Towell, 1971) and mechanical injectors for angiography (Rowe and Zarnstroff, 1965) have been reported. Our purpose is to report a case of electrocution caused by an artificial kidney during haemodialysis.

CASE DESCRIPTION

Haemodialysis was performed with a coil artificial kidney for eight hours twice weekly, through a cellophane membrane of 25μ thickness according to the standard accepted technique. Access to the blood stream was obtained through an A–V fistula.
Maintenance haemodialysis was carried out on a chronic uraemic patient (age 41) for more than two years. A good general condition was attained. The patient was hypertensive, with electrocardiographic changes compatible with left ventricular hypertrophy.

The day of the accident the patient came to the unit having gained 2.5 kg in weight. Blood pressure was 200/120 mm Hg, and the pulse rate of 84 was regular. Blood routine analysis revealed haematocrit 19%, blood urea 162 mg/%, potassium 6.5 mEq/l, sodium 132 mEq/l. Analysis of the dialysis bath demonstrated: glucose 215 mg/%, sodium 141 mEq/l, potassium 2.4 mEq/l, calcium 5 mg/%, osmolality 302 mOsm/l.

Forty-five minutes after haemodialysis was started the patient suddenly developed circulatory arrest but continued to breathe for 30 sec. Blood pressure was nil and cardiac sounds were not heard on the chest. Resuscitation efforts were unsuccessful. Post-mortem examination failed to disclose the cause of death.

Examination of the artificial kidney revealed a short circuited unearthed (ungrounded) thermostat. Examination with a microammeter detected a current leak of 42µA into the kidney and of 37µA in the dialysis bath. Simulation of the haemodialysis was carried out with saline. An electric current of 35–37µA was detected. When adequate earthing was undertaken the electric leak dropped to 4–7µA.

Six other coil kidneys were tested for current leaks. They were all grounded by means of three-prong plugs. No unit was free of electrical leak, which ranged between 2–11µA.

DISCUSSION

Ventricular fibrillation is easily produced by electric shock. Contact with outlets supplying 60 Hz alternating current (AC) presents the greatest hazard of electrocution (Leonard and Gould, 1965). Duration of exposure and current pathway largely determine human response to electric current. Ventricular fibrillation is not expected from stimuli under 10msec (Bruner, 1967) and specifically during the vulnerable phase of ventricular systole (Wiggers and Wegria, 1939). The most common pathway for electric accidental shock is the skin. The human body can be considered an electrolyte solution and the skin envelope offers resistance to the passage of electric current, which ranges between 1500 and 5000 Ω for 60 Hz AC (Keesey and Letcher, 1970). The lowest level of current perceptible through the skin ranges between 300µA and 1000µA (Bruner, 1967, 1971; Hopps, 1969; Keesey and Letcher, 1970). The cannot-let-go point, which happens when the subject is unable to release his grip on the electrical conductor ranges between 9 to 20 mA (Hopps, 1969). Ventricular fibrillation is induced with 100 mA (Bruner, 1967). But if the protective cover of the skin is lost, tiny voltages will cause substantial current to flow through the body tissues. When this unusual
pathway leads to the heart, ventricular fibrillation may be induced because of the high electrical sensitivity of the myocardium. An alternating current (60Hz) of strength 20μA applied directly to the heart suffices to induce ventricular fibrillation (Bruner, 1957, 1971; Hopps, 1969; Leonard and Gould, 1965). A cardiac catheter filled with saline is an excellent conductor carrying current directly to the heart (Leonard and Gould, 1965), moreover the 71 Ω/cm²/low resistance of plasma (Hamburger et al, 1964) makes a blood column connected to an electrically operated device an excellent pathway leading to the heart muscle (Bruner, 1967; 1971; Hopps, 1969; Leonard and Gould, 1965). The basic conditions and dynamics of haemodialysis strongly favour this kind of accident. Electrical leaks in the dialysis bath from thermostat and/or heating elements can easily pass through a thin cellophane low-resistance, large-surface, membrane leading to the myocardium through the blood column. Post-mortem examination fails to reveal pathological changes, so that microampere electrocution and ‘natural death’ are indistinguishable at autopsy (Bruner, 1967, 1971). Our case suggests that many cases of ‘unexplained cardiac arrest’ during haemodialysis may be due to electrocution in the microampere range. Safety precautions should be directed to the possibility of exposure of patients to electrical currents in the microampere range (Artley, 1970; Bruner, 1970). The earthing of artificial kidneys by methods commonly in use in hospitals seems far from satisfactory.

The European Standard by the International Commission on Rules for Approval of Electric Equipment, also adopted by the United States of America, states that leakage current from any electrical equipment must not exceed 0.5 mA (Keesey and Letcher, 1970), which clearly is far from safe in the case of electromedical devices which make contact with vascular tissue.

There is serious lack of adequate information about the ‘half-life’ of vital parts of electrical equipment, such as thermostats.

Adequate public control with stricter criteria, responsible manufacture and maintenance, and judicious use of electromedical devices are the clues to this serious and yet unsolved problem.

References


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