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An experimental model of an electrical injury to the peripheral nerve

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Abstract

Objective: Injury to the peripheral nerves is a common complication found in patients suffering from electrical burns. At present, there are many kinds of experimental models for electrical injury, but no report describes an animal-based experimental model for a relatively simple electrical injury to the peripheral nerves. We have designed and constructed a specific device to generate increasingly severe electrical shocks of a known voltage for the experiment. This device can simulate injuries of different degrees (minor, medium and severe) caused by shock to the right sciatic nerve of rats.
Method: Thirty Sprague–Dawley rats were randomly divided into Group I (3600 V, $n = 10$), Group II (1000 V, $n = 10$) and Group III (500 V, $n = 10$). The voltage required for the electrical shock was generated by the above-mentioned device and was adjusted to deliver 3600, 1000 and 500 V, respectively. The specific voltage, as mentioned above, was delivered three times to the right sciatic nerve of the rats. The shock duration was set to last for 10 ms. The time interval between the shocks was 3 min. Three rats were randomly selected from each group to observe changes in the morphology, electric physiology of the nerve and their histology the first, second and fourth week after injury.
Results: All rats survived the injuries. Leg function was partially impaired and swellings occurred on the injured extremity. However, by the second week after the injury the rats had recovered. Digit ulcers were observed by the fourth week after injury in Groups I and II. Neural electric physiology showed that the recovery rate of the neural conduction velocity (RNCV) disappeared in part or in whole immediately after the injury in experimental rats. RNCV recovered up to 65% in Group III and to 7% in Group II by the fourth week after injury, however, RNCV did not recover in Group I at all.

Histology showed that blood vessel embolism occurred within the injured nerve. A large number of nerve fibres experienced Waller degeneration while the myelin sheath was vacuolated. The neural plate disintegrated largely by the first week after injury and the myelin sheath disintegrated into a loose structure by the second week after injury in Group I. Group II displayed a similar situation as Group I, wherein some nerve fibres experienced Waller degeneration and disintegration. Regenerative myelin appeared in some rats at about the fourth week after injury. The following changes were seen in Group III: The degree of neural injuries was different. The point of entry of the electric currents showed obvious Waller degeneration and disintegration of the myelin sheath, while some nerves showed a regenerated myelin sheath by the second week after injury. The morphology (such as quantity and diameter) of the injured myelin was basically normal by the fourth week after injury.
Conclusion: This device can produce controlled injuries to the sciatic nerve giving different degrees of severity (minor, medium and severe), by means of varying the electrical shock voltage and shock duration on the rats. It is a useful model for experimental studies of injuries to peripheral nerves.

Keywords: Electrical injury; Sciatic nerve; Model; Experimental study

1. Introduction

Electrical injury is a common burn seen by clinics. It causes not only necrosis of skin and tissue but injuries to peripheral nerves are often seen, as the resistance of the nerves is low. Statistical data reported by Ferreiro et al. [1] indicate that patients suffering from electrical injuries caused by high voltage amount to about 3.8% of all burn patients in hospitals. The electrical current usually enters through the limbs during the electric shocks. Thirty per cent of all patients who suffered electric injury, suffered from injuries to peripheral nerves as well. Injury to the peripheral nerve is one of the most common complications in patients

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with an electrical injury. About 15% of patients with electrical injuries suffer from sequelae of various degrees of severity. Reports and data from the first national academic meeting of electrical injuries in China in 1992 showed that patients suffering from electrical injuries accounted for 6.6% of all burned patients in hospital. The injured area was mainly located in the limbs. The majority of the patients with electrical injuries simultaneously showed injuries of the peripheral nerve. This can cause a functional impairment and amputation rate. Therapy of the injured nerve is as important as therapy of the wounds in burned patients with neural injuries. Limbs without control of the nerve system are dead limbs without any real function. Since the mechanism of electrical injury is very complicated, treating neural electrical injuries becomes a difficult issue in the treatment of burned patients. We have designed the experimental model presented here to describe peripheral nerve electrical injuries in order enhance studies of this problem based on the summary of other experimental experiences [2–4]. The model simulates the procedure of a clinical electrical injury and presents a research proposal.

2. Materials and methods

2.1. Experimental apparatus

One single-phase booster was used (special transformer factory of Jiangxi). Output power was 2 kW; input voltage was 220 V; frequency of the alternating current was 50 Hz. The output voltages could be, respectively, 3600, 1000 and 500 V according to requirements of the experiment.

An electronic time controller (JSP-21) and time relay (JSP-79) offered by the electronic factory of Hangzhou were used to control the duration of the electrical shock. The duration ranged from 0 to 90 s. The contact fixed on the rat's leg was made in-house from plastics with good insulating characteristics.

The electrodes used for electrical injuries were made of stainless steel needles 1 mm in diameter, wrapped in an epoxy resin layer of 5 mm thickness (the exposed end of the needles was 1 mm long). As the end of the needles was rounded, the tip was sharpened in-house to less than 1 mm in diameter.

Other electric equipment, such as isolated electric wires, switches, sockets, voltage regulator, voltmeter, etc. were used to build the circuits.

2.2. Experimental method

Experimental conditions were set up according to the attached circuit diagram (Fig. 1). Thirty Sprague–Dawley (SD) rats were used. There was no restriction in regard to male and female rats. The weight of the rats was in the range of 220–250 g. The rats were randomly divided into three groups: Group I (n = 10) was shocked at 3600 V, Group II (n = 10) at 1000 V, and Group III (n = 10) at 500 V. One per cent isoamyl barbital (40 mg/kg) was injected into the abdominal cavity for anaesthesia. The right lower leg was epilated, using a depilatory cream. The approximate location of the sciatic nerve was painted on the skin using a watercolour paintbrush. The injured section was situated between 2 and 12 mm from the branch of the shin nerve and calf nerve, iodine disinfection and two stainless steel needles of the contact were inserted into both ends of the selected nerve section through the skin. The penetration depth was 2 mm. Using the specified device at currents of 3600, 1000 and 500 V, three separate shocks were given to each rat's sciatic nerve. The shock duration was set to last for 10 ms. The time interval between shocks was 3 min. Each rat was injected with 5 ml 5% glucose balance liquid into the abdominal cavity to avoid shock after the operation. Penicillin 400,000 U and 80,000 U Gentamicin were injected into the abdominal cavity every day in order for the rats to resist infection. The wound surface was disinfected with iodine at the same time. The rats were kept individually in separate cages.

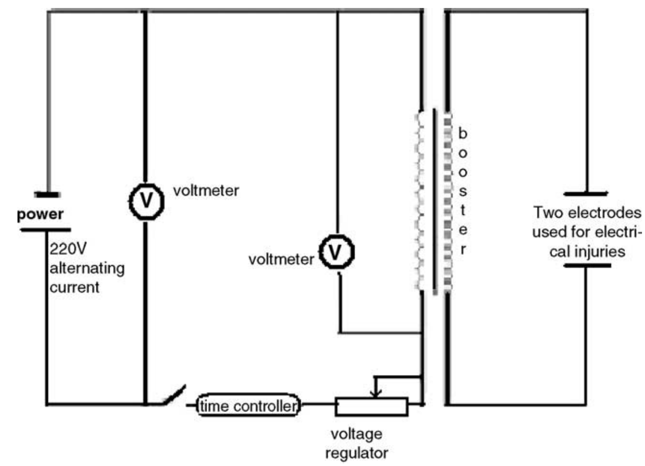

Fig. 1. Circuit diagram in the experiment.

2.3. Observation criteria

Three rats were randomly selected from each group for investigation at each of the three time points from point 1 to 3. The examinations took place in the first, second and fourth week after injury.

2.3.1. Examination of morphology in general

The injured rat's legs were observed for the occurrence of swelling and ulcer formation (especially digit ulcer or sole ulcer) on the skin. Furthermore reactions to stimulation and whether injuries came about easily (for instance, cold injury, hot injury and scratching injury) were observed. The wound-related recovery process was observed as well.

2.3.2. The examination of electrical physiology of the nerve

Electromyogram apparatus (Type DISA2000) was utilised to measure neural conduction velocity (NCV) on