Short Communications

An electron microscopic study of peripheral nerve regeneration with pulsing electromagnetic fields

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During the past twenty years, many findings of piezoelectrical phenomena in relation to bone formation have been reported in both the clinical and experimental fields. Since the first report was published, many investigators have demonstrated successful treatment of ununited fractures and failed fusions a variety of electrical stimulation techniques. The method of electrical stimulation was classified into three types: implanted electrodes, transcutaneous electrodes and non-invasive electromagnetic energy fields. Clinical use of non-invasive pulsing electromagnetic fields (PEMF) in the ununited fractures was most frequently cited, and several effects have been reported in the medical literature. Cellular calcium can be increased or decreased and enzyme action altered for cAMP, alkaline phosphatase-pyrophosphatase and collagenase under PEMF. We reported that PEMF stimulated bone repair as well as effecting neural regeneration when using electron microscopic techniques.

Thirty rats (250-300 grams) of the female SD strain were used. The sciatic nerve was exposed bilaterally from the sciatic notch to the popliteal space. With the aid of an operating microscope, perineural sutures were done, both medially and laterally, 5 mm. to the pyriformis muscle before transection. The sutures were tied under slight tension, leaving 0.5 to 1 mm. gap between the proximal and distal stumps. Post operatively, the rats were casted from the scapula to the ilium to assure constant position in the fields and to prevent pressure sores. These experimental animals were placed between a pair of vertical 18 cm round Helmholtz-aiding coils. The coils were driven by pulsing-shaping circuits which delivered a single, repetitive pulse, 380 micro sec. wide, quasi-rectangular in wave form and repeating 72 Hz. The amplitude was adjusted to produce a 15 mv output from a standardized coil probe. PEMF stimulation of 12 hours a day to the sutured nerves was administered to 15 rats for periods of 3, 4 and 6 weeks. The other 15 rats were kept in inactive coils as a control group.

At each interval of 3, 4 and 6 weeks after surgery, five rats were sacrificed in order to obtain the necessary histological specimens. A cross section of nerve specimens 5 mm distal from the transected area was made with Toluidine Blue stain.

Fig. 1 shows the electron micrograph of a cross section of the rat's regenerated sciatic nerve at 4 weeks after surgery. We see on the left, which is the experimental group, some regenerated myelin, unmyelinated axons and Schwann cells with early compartmentation. The control group, as shown on the right side of Fig. 1, shows a small number of regenerated myelinated axons without compartmentation. Morris et al. define compartmentation as the phenomenon of fascicular nerve repair. When axons penetrate to the nearest segments of the distal stump, compartments form in relation to the advancing axons, but do not form in those parts of the distal stump which have not been reinnervated. These findings might indicate that the compartmentation is dependent on the presence of axons, only developing in relationship to them. The early compartmentation of the experimental group indicates the early regeneration of the rat's sciatic nerve when compared with the control group.

There are indications that the regeneration process to the peripheral nerve is influenced by a number of local and systemic factors: thyroid hormones, adrenocorticotropic hormones, cyclic AMP, electro-

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magnetic fields and others. Pulsed electromagnetic fields have been shown to support neural regeneration in the sensory ganglia of the chick or rat in vitro. In an in vivo study, Raji et al.² designed experiments to repair the peroneal nerve of a rat, cut just above the knee joint. These animals received 15 minutes of PEMF treatment over a period of 8 weeks following injury. The authors reported dramatic effects of the PEMF, not only on nerve regeneration, but also on limb function. We reported that 5/15 Hz group of PEMF demonstrated only slight improvement in regeneration. It was reported that the 380/15 Hz regimen produced a significant and consistent effect on axonal outgrowth rate. Motor function returned after 4 weeks in the experimental group in contrast to 8 weeks in the control group³. The recovery rate of conduction velocities indicated a steep increasing statistical value in rats with PEMF compared with those in the control group within the first 4-6 weeks after surgery⁴.

Orgel et al.⁵ studied the effect of PEMF on the repair of the transected peroneal nerves of cats. These animals were placed in custom harnesses for 10 hours per day, so that the area of nerve repair would remain in the electromagnetic fields. The treatment was continued for 12 weeks, at which time the injured nerve was quantitatively assessed, both electrophysiologically and morphologically. In addition, the pattern of anterior motor horn cells labeled by retrogradely transported horseradish peroxidase (HRP) was studied. The authors concluded that pulse-burst electromagnetic stimulation can increase the number of motor neurons that re-establish appropriate connections to the periphery after transection and repair.

Electromagnetic fields may improve axonal regeneration as shown by this study of the electron microscopic findings of sciatic nerve regeneration of rats with PEMF.

References


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