Electrical Correlates of Peripheral Nerve Injury: A Preliminary Note[1]

R. G. Grenell and H. S. Burr

Yale University School of Medicine

In 1936 Burr, Lane, and Nims (*1*) described a new technic for the measurements of bioelectric phenomena. Their method was designed to discover whether or not living organisms possess potential differences, and, if so, to measure such differences independently of resistance changes and current flow. Further investigation showed that the apparatus met the ideal requirement, *i.e.* high input impedance (minimal current drain from the tissue), high stability, and high sensitivity. With this equipment available, the present experiments were undertaken to study potential differences of peripheral nerves (and of skin-surface areas) before and after injury and during degeneration and regeneration.

Three general types of experiments have been performed on rabbits and one on human cases, the sciatic nerve being used in all rabbit experiments and the ulnar nerve in the tests on human subjects: (1) direct measurements on peripheral nerve under various conditions; (2) measurements of limb surface EMF with the peripheral nerve undisturbed or blocked anatomically (nerve crushed or severed); and (3) measurements of limb surface EMF following physiological nerve block with procaine.

In all cases, measurements were made by means of the Burr-Lane-Nims microvoltmeter, described by them in 1936. Reversible, nonpolarizable, Ag-Ag Cl_2 brush electrodes were used, skin contact being assured by use of a salt electrode paste. The recorded data are in millivolts of potential difference between an indifferent electrode and an electrode moved from point to point along either a nerve or skin area.

In the first series of experiments, the sciatic nerve of the anesthetized rabbit was exposed in the thigh, and potential differences between an indifferent electrode on the skin of the leg and four selected points along the nerve proper were recorded. The second type of experiment involved similar measurements on the limb surface under normal conditions as well as following section or crushing of the nerve at the mid-point of the exposed area.

[1] The rabbits used in this study were provided in part under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and the Yale University School of Medicine. The study was aided by a grant from the Fluid Research Fund of the latter institution.

In the third series, rabbit sciatic nerves were infiltrated with 3 cc. of 4-per cent procaine without exposure of the nerve; in the human, ulnar nerves were infiltrated at the elbow with 3 cc. of 0.5- or 1-per cent procaine (in a few cases a procaine-adrenaline mixture was used). Records were made prior to injection, and following injection until the effects of the block had worn off.

The initial experiments in which measurements were made directly on the sciatic nerve in rabbits showed unequivocally that a potential gradient along the nerve is present. Distal points are negative to proximal. If the nerve is crushed so that the sheath is torn or traumatized, an injury potential is obtained (*i.e.* there is the expected peaking of the curve in the injured area).

Data obtained in the second type of experiment indicate that the potential differences recorded from the surface of the limb were modified by, or correlated with, the state of the peripheral nerve supplying the area. The acute effect of nerve section is a reversal in polarity of surface potentials.

These results led to an attempt to discover whether functional nerve block would be reflected in the surface measurements in a manner similar to physical or anatomical injury. In the rabbit, a series of six points on the skin, placed along the distribution of the sciatic nerve, showed a tendency toward significantly altered potentials following procaine injection of the nerve trunk. An hour following infiltration, many of these points showed a reversed polarity of considerable magnitude. This condition lasted for 45 minutes. Following this was a fall in potential until after the lapse of slightly more than two hours, when the potentials returned to approximately normal. This type of response is entirely absent when the degenerated sciatic nerve of the rabbit is infiltrated with procaine.

The results were so striking that a similar experiment was performed on human subjects. In these cases, three points were chosen along the hypothenar eminence lying within the area of distribution of the ulnar nerve. In the normal subject, as in the experimental animals, these three points show a marked shift in the measured potential difference.

In the case illustrated (Fig. 1), within 25 minutes after infiltration of the ulnar nerve with procaine, these three points were markedly positive. Twenty-five minutes later, with the return of flexor function, the potentials had dropped very considerably and continued to drop through the return of sensation and, after the lapse of three hours, had returned to their normal relationships. This can be clearly seen in Fig. 1. The polarities represented here are those of the moving electrode.

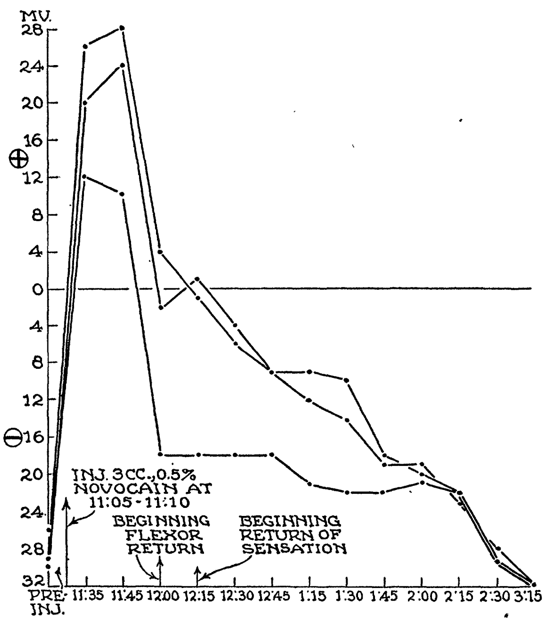

FIG. 1. Effects of left ulnar nerve block in man following injection of 3 cc. of 0.5-per cent novocain-suprarenin (1 : 50,000).

In man, procaine block produces changes of as much as 50–60 mv in the surface EMF of the functionally disturbed area. The curves in the human cases are much more striking than those of the rabbits, perhaps due in part to the fact that the rabbit nervous system was partially depressed, initially, by anesthesia.

It is clear from the results of these experiments that the condition of the peripheral nerve is reflected in the changing surface potential differences. The mechanism through which these changes are brought about is now being studied, and a clinical test for peripheral nerve injury is being developed.

Reference

1. BURR, H. S., LANE, T. C., and NIMS, L. F. *Yale J. Biol. Med.*, 1936, 9, 65–76.

Spinal Conditioning in Dogs

W. N. KELLOGG, N. H. PRONKO, and JAMES DEESE
Conditioning Laboratory, Indiana University

One of the most striking observations of recent years in the field of psychology and neurophysiology has been the observation that learning—or what appears to be learning of a rudimentary sort—can occur in the caudal extremities of higher vertebrates after the spinal cord has been completely transected. This would seem to mean that the organism, or a fragmentary part of it, can form simple associations without the aid of the cerebrum or of any of the higher centers of the central nervous system, and that these centers are therefore unnecessary for the occurrence of learning of the sort indicated.

The most extensive series of investigations on this topic has been conducted by Culler and Shurrager (*1, 2, 3, 4*), who used *acute* spinal dogs as experimental subjects. Their method was to pair an electric shock to the tail (the conditioned stimulus) with an electric shock to the foot (the unconditioned stimulus). Before training, the shocks to the tail produced no observable response in the flexing (semitendinosus) muscle of the leg; but after pairing of the conditioned and unconditioned stimuli, the tail shocks by themselves would then cause the semitendinosus muscle to contract.

We wish to report here some recent experiments at Indiana University in which conditioned-reflex training of a similar nature was attempted with *chronic* spinal dogs. A more complete account of the findings will appear subsequently in the psychological journals.

The conditioned stimulus in the present experiments was an electric shock to the left rear foot, and the unconditioned stimulus was a shock to the right rear foot. The response to be conditioned was the moving or flexing of the entire right hind limb. Each of the subjects was given 1,000 conditioning trials in groups of 100 trials each, spaced on alternate days over a period of about three weeks.

Despite the differences in experimental technique between the two investigations, there was clear evidence in each of our preparations that a muscle twitch or instantaneous jerk of the right rear leg could be evoked by the conditioned stimulus to the left rear foot. The twitch response was small in amplitude and of very short latency. We assume this twitching movement of the right rear member to be the same as the spinal conditioned response observed in the acute preparation by Shurrager and Culler.

The twitch response observed in our chronic spinal animals, however, was only a part of the behavior elicited by the conditioned stimulus. The records of movement of the right hind limb also disclosed a second and conflicting type of reaction. In place of the muscle twitch or incipient *flexion* there often occurred an *extension* of the right rear limb, *i.e.* the crossed extension reflex. Although the extension response was initiated immediately by the conditioned shock, it usually lasted for from two to three seconds. With respect to duration it had no resemblance, therefore, to the very brief jerk of the flexing muscles.

The two sorts of reflex movements were antagonistic and mutually inhibitory. They never occurred together on the same trial. One response would usually pre-