AN ELECTROPHYSIOLOGICAL STUDY OF NERVE再生 IN THE CAT

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(Received for publication September 30, 1954)

Innumerable anatomical studies reflect an abiding interest in nerve repair. In most respects clinical observations have confirmed and extended the anatomical, but complementary electrophysiological studies are also necessary. There have been few of these. A considerable share of clinical interest centers about the return of sensation, and particularly this aspect of nerve regeneration should be advanced by electronic recording techniques.

Berry, Grundfest and Hinsey1 and Berry and Hinsey2 studied the conducted potentials of cut and sutured nerves of the cat in vitro using the sciatic, its tibial and peroneal branches, and the saphenous. They examined cat nerves at intervals of 17 to 466 days following suture, and their results indicated a close adherence to the relations that prevail between fiber size and conduction velocity in normal preparations. As regeneration proceeded they observed that conduction velocity showed a definitive relation to elapsed regeneration time, although complete recovery of speed was not obtained even at the longest intervals studied. Erlanger and Schoeple3 studied crushed nerves of the cat in vitro, principally the phrenic; their results indicated that conduction time from above to different distances below a neuroma was not a linear function under 190 days. This they related to tapering of the regenerating fibers. That result appears to be at variance with a discussion note by Grundfest,4 but in part at least the difference may have been attributable to variations in the techniques employed.

We wished to compare for the same animal the characteristics of regeneration in cut and sutured and in crushed nerves, and to examine the potentials evoked in the posteroventral thalamic nucleus by volleys excited electrically from opposite-sided regenerating segments. It was believed the latter might have significance because of the frequently drawn analogy between sensory disturbances associated with human thalamic lesions and the altered sensations that occur during the regeneration of nerves into skin areas. The superficial radial nerve of the cat was selected for our purpose because it is principally sensory in function, and the locus of its thalamic potential can be detected readily by a probe electrode directed into the thalamus.6,7

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METHOD

Under sterile conditions (nembutal anesthesia) both superficial radial nerves were exposed in each of 31 cats. One of the pair was crushed at the elbow with a small hemostat, and the other was cut across and sutured with interrupted silk epineural sutures. Following operation the animals were examined at frequent intervals to detect the presence or absence of response to light touch, pin prick and pressure applied over the cutaneous distribution. A response to noxious stimulation was routinely obtained from skin previously innervated by either a cut or a crushed nerve at 15–20 days postoperatively. Since this was too early for regeneration to have proceeded to the skin terminals we attributed the finding to overlap. Only 2 animals of the series showed hyperirritability to touch, and these at 60 and 70 days regeneration.

The experimental procedures were also done under nembutal, the animals being used at planned intervals to provide a chronological series between 20 and 180 days. The head was fixed in a holder and a stereotaxic device was used to lower a steel recording electrode (100 μ tip exposure) through exposed cortex to the thalamic locus for the superficial radial nerve. To detect that locus stimulating electrodes were applied to the opposite superficial radial (above the neuroma) before the nerve was freed for recording.

Tripolar electrodes (2 grids and ground) were used for in vivo stimulating and recording. These were so arranged that a stimulating cathode (X) situated 25 mm. proximal to the neuroma was separated by 50 mm. from the nearest recording electrode (Y) of another such tripole situated below the neuroma. A third tripole (Z) was situated further distally, its proximal recording electrode being placed 100 mm. below point X. With minor adjustments the combinations available upon the tripoles enabled us to record different stimulus-response combinations between points X, Y and Z, the 3rd electrode of each tripole serving as needed as a ground point. Each series of records was commenced by recording the evoked thalamic response from points X, Y and Z respectively. Thereafter the nerve was cut above X and the remainder of the records were obtained between points upon the nerve. In each instance we attempted to record monophasically, crushing the nerve under the further removed recording electrode and applying KCl to the cut end. A Grass stimulator was used to deliver single shocks of 0.1 or 1.0 msec. duration. Its output was delivered through an isolation transformer, and a Wheatstone bridge was often used to balance capacitance and resistance changes in the nerve.

At the end of each experiment both nerves were removed and fixed in position (15 per cent formalin) upon cardboard with the sites of the X, Y and Z electrodes’ positions marked. Later blocks were cut for osmication and sectioning to reveal the fiber distributions at each of the 3 points, and companion unosicated blocks were sectioned and stained by Bodian’s method for myelinated plus nonmyelinated fibers.

OBSERVATIONS

Fig. 1 illustrates pairs of conducted nerve potentials and evoked thalamic responses for crushed and for cut and sutured nerves recorded 20, 30, 90 and 180 days following operation. All nerve records illustrated were obtained with the stimulating point 25 mm. above (X) and the proximal recording electrode 25 mm. below (Y) the neuroma. Thus, each of these averages conduction over normally rapid upper, and lower, more slowly conducting, re-