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Electrode Efficiency and Subject Positioning in Electromyography.

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The increasing use of motor unit action currents, in clinical as well as fundamental studies, has led to the need for a better understanding of certain basic technical problems which are constantly encountered. Some of these are: the efficiency of various electrode contacts, the effect of attitudinal reflexes and positioning of the part under examination and the voltage recorded *in vivo*. This report deals with these problems, some of the data having been accumulated from previous work and some from recent experiments.

Methods. Electrode Comparison. Four kinds of electrodes were tested to determine their relative efficiencies: (1) a perforated, circular, silver skin-pad with an outside and inside diameter of 7 mm and 4 mm respectively, (2) an enameled electrode† consisting of a 25-gauge hypo needle enameled to within 2 mm of its tip, (3) the core and (4) the shaft of a concentric electrode (copper core in a 22-gauge hypo needle).

The 4 electrodes were arranged in a cluster with the concentric electrode inserted through the aperture of the skin-pad to a depth of 5/8″ to 1″ and the enameled electrode at an angle from outside the skin-pad, its tip being a few mm from the tip of the concentric. An intradermal hypo needle (the indifferent electrode) was placed several cm from the others. Small intradermal wheals of 1% procaine hydrochloride allowed painless insertion of the needles.

A keyboard permitted pairing of the 4 active electrodes in any combination or with the indifferent electrode, giving 10 combinations. These led to dual channel (Offner type 140) balanced amplifiers feeding an audio amplifier, a cathode-ray oscilloscope and Westinghouse bifilar galvanometers for recording on bromide paper. The subject contracted the muscle very slightly until a single unit was heard from one of the electrodes paired with the indifferent. This unit was fed into one channel while the other 9 combinations were fed alternately into the second channel. Since synchronization of different units does not occur in normal muscle, the voltage of any unit recorded on the combinations comprising the test channel, and in step with the unit on the test channel, could be determined.

The muscles used were the deltoid, biceps and triceps brachii, sacrospinalis mass and those of the dorsum of the hand between the thumb and index finger. The subject was seated comfortably at a table with the part being examined in a neutral position, or prone with the head in the midline. Usually the level of contraction employed did not cause visible movement.

Results. Electrode Comparison. A comparison of the pickup efficiency of 4 different types of electrodes using 25 different units revealed that the highest voltage was recorded on an enameled electrode 17 times, on the core of a concentric 7 times, and was identical on the enameled electrode and the shaft of the concentric once. A skin-pad failed to show the highest voltage in any instance. The highest 4 voltages for an enameled electrode were 450, 420, 400 and 300 μ v, for a core 260, 240, 200 and 200, for a shaft 90, 80, 70 and 60, and for a pad 60, 30, 20 and 20. Voltages were picked up by an enameled electrode in 23 of the 25 units, by a core in 20 (plus one questionable), by a shaft in 17, and by a skin-pad in only 8 (plus one questionable).

With 21 of the 25 units there were 2 or more electrodes in the pickup range. In 16 of these the voltage recorded by a single electrode paired with an indifferent was as high or higher than that recorded by pairing two electrodes

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† This type of electrode was suggested to us several years ago by Dr. A. S. Gilson.

in the field.‡ These included instances where the pickup of the enameled electrode, paired with the indifferent, was 160 μ v greater than the combination of this electrode with another in the field (enameled electrode and core) and where the pickup of the core paired with the indifferent was 110 μ v greater than that of the core paired with the shaft. In only 3 units did a pairing of two electrodes in the field record greater voltage than did each single electrode when paired with an indifferent.

In no instance did a pairing of two electrodes pick up the unit action potential when each, paired with an indifferent, was out of the field.

With one electrode in the field and two or more showing no pickup (hence serving as additional indifferents), in 10 instances the active electrode recorded more voltage when paired with one indifferent than with another.

Voltage characteristics. Since with *in vivo* preparations electrode position relative to units cannot be duplicated in repeated experiments, there would be no point in attempting to determine the average voltage of a single unit action potential. However, in measuring several hundred unit action potentials under conditions similar to those already described, one of us (J.S.D.) working with Dr. Charles C. Hassett[1] found those higher than 500 μ v to be extremely rare. The highest observed was 1000 μ v, and in this experiment another electrode a few mm away failed to record this action potential.

Pickup range. It was found that although two closely placed electrodes might not show action potentials when paired, a pairing of one of the two with one of a similar distant pair will show action potentials from muscle masses other than those in which the electrodes are placed. In such instances the potentials recorded are those of many units.

Attitudinal reflexes and tension. In addition to the presence, at times, of muscle action potentials from attitudinal reflexes, it was observed that positions of almost imperceptible "tension" of the part being examined resulted in minor contraction. Under normal circumstances this can usually be quieted, at least as far as single unit potentials are concerned, by a more comfortable positioning of the subject.

Discussion. Electrodes with more contact surface than the core of a concentric but less than the bare shaft are most effective in recording muscle action potentials. This is in line with previous observations made with enameled electrodes.[1] With 2 electrodes in the field, cancellation of potentials is apparently greater than augmentation and indicates that a single exploring electrode (with an indifferent) will sample an area more effectively than will 2 electrodes. Cancellation or leakage, or both, make bare needles inefficient for studies of single units, and skin resistance or distance from the active locus, or both, similarly decrease the effectiveness of skin-pads.

The observation of action potentials recorded by one electrode but not by another even though they be separated by only a few mm indicates that care must be exercised before reaching the conclusion that no contraction is present in the area being sampled by only one or two electrodes. While we agree with others[3-5] that normal resting striated muscle has no contraction and hence no action potentials, such an observation can be made only with multiple and efficient electrode pickup. However, since extremely minor voluntary or reflex contraction fires many motor units, the use of the less efficient bare needles or skin-pads is frequently satisfactory for determining relative degrees of contraction in the muscles being observed.

It is apparent that the voltage of a unit action potential as it is recorded with extracellular electrodes at some distance from the active locus is but a fraction of that recorded with intra- and extra-cellular microelectrodes in single fibers.[2]

When resting muscle is being sampled for

‡ In comparing the pickup of various electrodes and combinations, differences of less than 20 μ v were discarded since such differences might result from slight electrode movement.

[1] Denslow, J. S., and Hassett, C. C. *Am. J. Physiol.*, 1943, **139**, 652.

[2] Gerard, R. W., *Electrophysiology. Ann. Rev. Physiol.*, 1942, **4**, 329.

[3] Jacobsen, Edmund, Progressive relaxation, Chicago, University of Chicago Press, 1938, 493 pp.

[4] Lindsley, D. B., *Am. J. Physiol.*, 1935, **114**, 90.

[5] Smith, O. C., *Am. J. Physiol.*, 1934, **108**, 629.

contraction, the electrodes must be kept close together (within a few cm) to eliminate the possibility of picking up potentials from distant muscles. In addition, attitudinal and myotatic or stretch reflexes from improper positioning must be avoided when resting muscle is being sampled for contraction. This often requires that the subject recline with the face in the midline and with the knees and arms slightly flexed, in a position of absolute comfort.

On the basis of these observations, it is evident that reports dealing with electromyograms should describe the type and placement of electrodes and the positioning of the subject.

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Effects of Morphine, Nembutal, Ether, and Eserine on Two-Neuron and Multineuron Reflexes in the Cat.

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In the spinal cat, small doses of morphine (5 mg per kg) cause diminution in the amplitude of the flexor reflex, but leave stretch reflexes unaffected or slightly enhanced.[1] This differential action has now been investigated by a study of effects on transmission through two-neuron and multineuron reflex arcs in the spinal cat, since it is known that stretch reflexes traverse the former,[2] while reflexes of cutaneous origin traverse the latter[3] pathway. The effects of morphine have been compared with those of nembutal (sodium ethyl, 1-methyl-butyl barbiturate), ether, and eserine (physostigmine salicylate).

Methods. The experiments were performed on adult cats that had been made spinal at the first cervical segment under ether anesthesia. Respiration was maintained artificially and full recovery from the anesthesia was attained before making the study. The lumbosacral spinal cord was exposed by laminectomy and monophasic leads were taken with chlorided silver electrodes from ventral roots L_7 and S_1 severed from their peripheral connections. The nerves to the gastrocnemius muscle, the sural, and one or both branches of the common peroneal nerve were exposed in the ipsilateral hindleg, crushed distally and placed on chlorided silver wire electrodes for stimulation. All exposed nerve tissue was covered with paraffin oil at a temperature of 38°C. Heat was applied to the animal externally. In some experiments, stimulating electrodes were placed on ipsilateral dorsal roots; in others, reflex responses were recorded from a peripheral nerve. Stimulation was effected by single condenser shocks supramaximal for A fibers. Action potentials were recorded photographically by means of an amplifier and cathode ray oscillograph. Ether was administered through the artificial respiration airline by means of a bottle with a regulating valve. The other drugs were freshly prepared (aqueous solutions) and injected intravenously.

Results. A. *Morphine.* Small doses (5 mg per kg) of morphine sulfate regularly enhanced reflex discharges through two-neuron arcs and depressed those through multineuron arcs (Fig. 1). These effects appeared in from 2-15 minutes and persisted for several hours. Larger doses of morphine (15 mg per kg) depressed also the two-neuron arc discharges in experiments in which the reflex was from peripheral nerve to ventral root. The most note-

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1 Wikler, A., *J. Pharmacol.*, 1944, **2**, 176.

2 Lloyd, D. P. C., *J. Neurophysiol.*, 1943, **6**, 317.

3 Lloyd, D. P. C., *J. Neurophysiol.*, 1943, **6**, 293.