THE EXTENT AND NATURE OF THE SENSORY LOSS IN MUSCULOSPIRAL PARESIS.

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The musculospiral nerve is one of the peripheral nerve-trunks of the body most commonly affected by injury. Especially often have lesions of it occurred during the present War—lesions either primary, due to actual contact with or proximity to the nerve of the foreign body in its passage into or through the tissues of the arm, or secondary, division anatomic or physiologic, complete or incomplete, due to such results of the entrance of the bullet or piece of shell as fractured bone, abscess development or formation and contraction of fibrous tissue. In a series of twenty cases of injury to nerve-trunks of the upper limb, collected by the writer during the earlier months of the War, the musculospiral was involved in six cases; in half of these it was the only nerve to suffer, in the other three there was a concomitant injury to at least one other trunk.

The musculospiral is the nerve-trunk of the upper limb, in which the area of sensory loss resulting from its complete division has given rise to most misunderstanding and discussion. Since the epoch-making discoveries associated with the names of Head and Sherren, and even before this, a more or less definite area, variable within certain small limits it is true, with the position of the nerve lesion and with other different physical and anatomical conditions—but still a more or less definite area of sensory loss has come to be associated with and recognized as the result of complete division of the various nerve-trunks of the body. The musculospiral nerve, however, is somewhat different; the area of its sensory loss is still a matter of controversy in many cases, and, as regards certain points, is far more variable—a variability depending apparently on more complicated anatomic and physiological arrangements, affecting not only the whole area of sensory loss in degree and extent, but also the relationship to each other of the areas of loss of epicritic and protopathic sensibilities. Indeed, one case of the present series seems to prove that to the general law of Head and Sherren that "in all peripheral nerves the fibres subserving protopathic sensibility have a much wider
overlap than those subserving epicritic sensibility," the musculospiral must be considered a possible, or at least an apparent, exception.

The writer using his six cases as illustrations proposes to study these variations in the sensory loss of the musculospiral nerve, and to see how far known anatomic connexions and hypothetical physiologic arrangement can be made to explain them.

The sensory loss when the nerve-trunk is divided in the lower third of its course in the arm below the point of origin of its external cutaneous branches:-

Many cases have been recorded of this lesion by various writers without the occurrence of sensory loss at all—notably Sherren's cases and one by Parry, where two inches of the nerve was destroyed in this position without loss of sensibility on the dorsum of the hand; indeed, Sherren writes "that complete division of the musculospiral nerve in its lower third produces no alteration in the sensibility of the dorsum of the hand."

The following case, although in it there is an accompanying ulnar paresis, fortunately not seriously affecting the points at issue, shows that it is possible that this may not be an absolute rule without exception. This point will be discussed after giving the case.

Case 1.—Division of ulnar and musculospiral nerves in the lower third of the arm, with an area of sensory loss in the hand. Private E. F., aged 24, was wounded by a piece of shrapnel casing in the lower third of the left arm on April 26, 1915. Septic wounds of entrance and exit resulted without the occurrence of any bony lesion.

On examination, May 16, 1915, the following was found to be the condition:-

Position of Limb.—A combination of drop wrist and main-en-griFFE.

Motor Loss and Powers.—Can flex all fingers at the proximal interphalangeal joints, can flex the three outer fingers, index, middle and ring fingers, at the distal interphalangeal joints; cannot flex the distal interphalangeal joint of the little finger; can adduct and abduct all the fingers, the interossei and hypothenar abductor of the little finger being felt to contract; can adduct the thumb; can extend the interphalangeal joints of the fingers, but cannot extend the interphalangeal joint of thumb; cannot extend the metacarpophalangeal joints; cannot extend the wrist, but can contract the biceps, triceps, and extensor carpi radialis longior.
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Electrical Reactions of the extensors of the posterior interosseous group except the extensor carpi radialis longior; no reaction to faradism; with galvanism A.C.C. > K.C.C.

Sensory Loss.—As in Diagram I. From these data the diagnosis can readily be deduced; both from the position of the wounds and from the fact that the extensor carpi radialis longior contracts whilst the rest of the extensors give the reaction of degeneration, one diagnoses a complete division, anatomic or physiologic, of the lower third of the musculospiral nerve after it has given off its external cutaneous branches and the motor branch to the extensor carpi radialis longior. Of course in addition there is an incomplete ulnar paresis.

Case I.—Diagram I: Area to ulnar side of line A B = area of epicritic loss; area to ulnar side of line A' B' = area of protopathic loss; area to ulnar side of line a b = area of deep loss.

When we come to study the sensory loss in this case (Diagram I) it will be seen that the area of loss of deep sensibility is merely that which occurs in pure ulnar paresis, but that the area of epicritic loss on the dorsum of the hand is considerably larger and extends further towards the radial border of the hand than if the ulnar nerve alone had been affected. Hence we have here a lesion of the lower third of the musculospiral producing an area of at least epicritic loss on the back of the hand; such however will occur, according to Sherren if the external cutaneous branches of the
nerve are cut as well as the nerve trunk below their point of origin. That this may have happened in this case is certainly a possibility; unfortunately because of the septic nature of the wounds and for other reasons operative investigation of this point was impossible. If these external cutaneous branches had also been cut, however, Cases 2, 3, 4, and 5, as will be seen—would certainly lead one to expect that in this case (1) there would have been an area of sensory loss along the back of the forearm, but this again, we shall see, need not necessarily follow the division of the nerve and its external cutaneous branches. Hence we must conclude that the evidence in this case, although suggestive of the possibility of a lesion of the lower third of the nerve alone producing an area of sensory loss, is indecisive.

It should be noticed in passing that in this case the area of sensory loss involves the ulnar rather than the radial half of the area on the dorsum of the hand supplied anatomically by the radial nerve.

The sensory loss where the nerve trunk is injured above the lower third of the arm—above the point of origin of its external cutaneous branches:

In these cases all authorities are agreed that there occurs some sensory loss, although many hold this area of loss is limited to the dorsum of the hand and does not occur on the back of the forearm unless the posterior division of the musculocutaneous nerve is injured in addition to the whole musculospiral. The following cases however prove conclusively that this is not so and that an area of sensory loss may occur on the back of the forearm in complete musculospiral division in the absence of musculocutaneous division.

Case 2.—Complete division of the musculospiral just below the lower border of the axilla with areas of loss of sensation both in the forearm and hand.

Private A. M., aged 30, was wounded on September 10, 1914, by a rifle bullet in the upper half of the right arm. Condition on examination March 17, 1915:

Position of Limb.—Complete wrist-drop, forearm pronated, elbow flexed, wasting of long extensor muscles on the back of the forearm.

Motor Loss and Powers.—Cannot supinate, cannot extend metacarpophalangeal joints, nor wrist joint, nor interphalangeal joint of thumb; no contraction of supinator longus, very slight amount of contraction of part of triceps.
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Electrical Reactions.—No reaction of paralysed muscles to faradism, slow contraction to galvanism.

Sensory Loss.—See Diagram II. No loss of deep sensibility, losses of epicritic and protopathic sensibilities as in Diagram II.

Case 2.—Diagram II (a): Areas of loss of epicritic and protopathic sensibility in hand.

Case 2.—Diagram II (b): Areas of loss of protopathic and epicritic sensibility in the forearm.

Hence with these facts the diagnosis was complete, viz., division of the musculospiral nerve in the upper third of the arm after it had given off at least some of the motor branches to the
triceps. Subsequent operation showed this to be correct, the nerve being completely divided below the point of origin of the branch to the inner head of the triceps and only with difficulty were the two ends dissected out, freshened and reunited.

Here, then, is a case where from the position of the bullet wounds and track it was impossible for the posterior division of the musculocutaneous to be divided and yet a very considerable area of sensory loss, not only in the hand but on the back of the forearm, resulted from complete division of the musculospiral nerve in the upper third of its course. The same phenomenon is exhibited by

Case 3.—Diagram III (a).

Case 3.—Diagram III (b).

Case 3.—Complete division of the musculospiral secondary to compound comminuted fracture of the shaft of the humerus with areas of sensory loss in forearm and hand. Private H. C., aged 23, wounded on October 27, 1914, by pieces of shrapnel which produced
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a compound comminuted fracture of the humeral shaft about its middle. On examination March 8, 1915, all wounds had healed and the following was the condition.

**Position of Limb.**—Complete wrist drop, great wasting of extensor muscles on the back of the forearm and of the triceps.

**Motor Loss and Powers.**—Cannot extend metacarpophalangeal joints nor wrist joint, triceps contracts feebly, supination performed by the biceps.

**Sensory Loss** as in Diagram III. In this case it was noticed that on shaving the forearm preparatory to testing the sensation there was a great accumulation of epidermis, the result of delayed desquamation over an area corresponding almost exactly with that of the epicritic loss as shown in the diagram.

At operation there was found in place of the musculospiral nerve mere strands of fibrous tissue partly embedded in and partly stretched over the callus. On stimulation of the nerve above the lesion there was no contraction at all of any paralysed muscle; in other words the block was complete.

Here again there was no question of simultaneous involvement of the musculocutaneous nerve.

**Case 4.**—Complete division of the musculo-spiral in the musculospiral groove secondary to a fracture of the humeral shaft with areas of sensory loss on forearm and hand.

Private J. O., aged 21, was wounded February 14, 1915, in the middle of the left arm by a piece of shrapnel which passed completely through the arm leaving septic entrance and exit wounds, and causing a compound fracture of the middle of the shaft of the humerus. Condition on examination, March 25, 1915:

**Position of Limb.**—Wrist-drop, arm pronated.

**Motor Powers and Loss.**—Cannot extend metacarpophalangeal joints but can extend all the interphalangeal joints, except that of thumb; cannot extend wrist; paralysis of the supinator longus; biceps alone supinates; triceps contracts.

**Electrical Reactions.**—The paralysed muscles do not contract at all on faradic stimulation. On galvanic stimulation A.C.C. > K.C.C.

**Sensory Loss.**—No loss of deep sensibility, areas of loss of epicritic and protopathic sensibilities as in Diagram IV.

The diagnosis is obviously complete division of the nerve above the lower third above the point of origin of the motor branch to the supinator longus and the external cutaneous branches. That this was correct was proved at operation, a complete anatomical division being found in the musculospiral groove.
Here, again, there is a case of complete musculospiral division without musculocutaneous division showing an area, smaller, it is true, than in Cases 2 and 3, of loss of sensibility in the skin of the forearm. This case is remarkable in that, as regards the area on the hand of sensory loss, the area of protopathic loss overlapped to a considerable extent the area of epicritic loss. This was tested over and over again most carefully, and ascertained to be so beyond doubt. To the discussion of this apparent exception to Head and Sherren's law relating to peripheral nerves we will return later.

Case 4.—Diagram IV (a).

Case 4.—Diagram IV (b).

Case 5 shows the sensory loss that may occur with simultaneous division of the musculospiral and ulnar nerves in the upper half of the arm.

Private F. H., aged 33, was wounded on November 1,
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1914, by a rifle bullet which passed through the inner side of the arm just at the lower margin of the anterior axillary fold fracturing the surgical neck of the humerus. On examination, March 17, 1915, the wounds had healed and the bone united.

*Position of Limb.*—Drop wrist; forearm pronated; elbow flexed; great wasting of one half of the thenar and all the hypothenar muscles and also the interossei, also the muscles on the back of the forearm.

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Case 5.—Diagram V.

*Motor Loss.*—Complete paralysis of muscles supplied by the ulnar nerve. Inability to extend metacarpophalangeal, interphalangeal of thumb and wrist joints.

*Sensory Loss.*—See Diagram V.

Loss of deep sensibility as in pure ulnar paresis, cf., diagram I.; loss of joint sense in little finger only, loss of epicritic and protopathic sensibilities as in Diagram V.

Operation confirmed the diagnosis of complete division of the ulnar and musculospiral nerves. The lower end of the upper bony fragment was densely adherent, projecting inwards as it was, to the third part of the axillary artery, and the musculospiral nerve, on electrical stimulation of which proximal to the lesion no contraction of muscle occurred. The ulnar nerve was found in a mass of scar tissue with a spindle-shaped enlargement on it. Proximal electrical stimulation of it also produced no muscular response. This then is another example of complete division of the musculospiral nerve with an intact musculocutaneous, resulting in
loss of sensation over a considerable strip of skin on the back of the forearm.

It is interesting to compare the sensory loss area on the dorsum of the hand—or the musculospiral portion of it—in Case 5 with that in Case 1, where there was complete division of the musculospiral in the lower third; in Case 5 this area is much more extensive than in Case 1, although in both cases it is the radial portion of the area anatomicly supplied by the radial nerve that retains its sensation. This, again, differs from what occurs in Cases 2 and 3 where it is in this radial portion of this area that sensation is chiefly lost.

Case 5.—The diagram of this case is instructive inasmuch as it shows the areas of sensory losses in a case of injury to the ulnar, median, musculospiral, internal cutaneous, and musculocutaneous nerves occurring just above the bend of the elbow in the lower third of the arm. In this case the external cutaneous branches of the musculospiral escaped.

Private F. H., aged 23, was wounded in the lower part of the right arm, a large piece of skin and muscle having been cut away from the antero-internal aspect of the lower third of the arm by a piece of shell. Investigation of his case on February 27, 1915, when the wound had completely healed, showed an incomplete division of the larger and deeper trunks—ulnar, median, and musculospiral, and a complete division of the subcutaneous nerves—the internal cutaneous and the musculocutaneous.

Diagram VI shows the various areas of sensory losses.

In this case we have the reverse of what obtained in Cases 2, 3, 4 and 5. In them there was division of the musculospiral nerve including the fibres which become the external cutaneous branches and no lesion of the musculocutaneous, resulting in an area of sensory loss extending from the level of the olecranon downwards a varying degree; in Case 6 on the other hand, division of the musculospiral, less the external cutaneous branches, but with musculocutaneous division, yields an area of sensory loss extending up the back of the forearm hardly more than half way and leaving with sensation intact a large part of the area affected in the other four cases. Compare here Diagrams II, III, IV and V, with Diagram VI.

Thus these five cases between them furnish a double proof that to produce sensory loss along this area in the forearm, it is not necessary, as some have maintained, that a musculocutaneous lesion should co-exist with a complete musculospiral above the lower third.
Résumé of facts exhibited by the cases:—

1. In no case of pure musculospiral paresis is there any loss of deep sensibility.

2. Complete uncomplicated division of the musculospiral nerve in its lower third results in most cases in no loss of cutaneous sensation, but it is not proved that this is an absolute rule, for case 1—suggests at least that there may in some cases result an area of sensory loss on the dorsum of the hand.

3. Complete division of the musculospiral nerve in its lower third complicated by simultaneous division of the posterior branch of the musculocutaneous, or the external cutaneous branches of the musculospiral, produces an area of sensory loss on the back of the hand (Sherren).

4. Complete uncomplicated division of the musculospiral nerve above its lower third—above the point of origin of the external cutaneous branches—results in an area of sensory loss on the back of the hand; this alone in some cases (Sherren), but Cases 2, 3, 4, 5, 6, prove that in addition, without any simultaneous musculocutaneous injury there may occur an area of sensory loss on the back of the forearm.

5. The area of sensory loss on the dorsum of the hand involves areas, both of epicritic and protopathic loss, and it varies in extent in different cases.

6. This area on the back of the hand, in some cases lies more...
to the radial side, and in other cases more to the ulnar side of the area of skin anatomically supplied by the radial nerve.

(7) Where division of the musculospiral nerve produces an area of sensory loss on the dorsum of the hand, Case 4 shows that the area of protopathic loss may overlap and extend beyond the area of epicritic loss, whereas it has always been held that in cases of injury to peripheral nerves the former area is included within the latter.

(8) Where there is an area of sensory loss on the back of the forearm it varies greatly in dimensions in different cases.

Hence we see that the variations in sensory loss in division of the musculospiral nerve may be classified as follows:

1. Variations in extent of the area of sensory loss.
2. Variations in position of the area of sensory loss.
3. Variations in proportion between the epicritic and protopathic loss areas.

**Variations in Extent of the Area of Sensory Loss.**—As regards the area of sensory loss on the back of the forearm, variations in its size are explicable on the ground of the known variations of size of the inferior external cutaneous branch of the musculospiral nerve; cases of the non-existence of this area in musculospiral paresis are probably cases where this inferior branch supplies a smaller area of skin than usual, and where the area it does supply is also supplied by overlapping of contiguous cutaneous nerves. In such a case, a definite area of sensory loss would occur only if the musculocutaneous or its posterior division were cut also.

In all cases of peripheral nerve division, of course, the area of sensory cutaneous loss—of epicritic loss—never equals in extent the area anatomically supplied by the affected nerve, this being due to overlapping and supply of the periphery of this anatomical area by nerves supplying the surrounding skin. As will be seen on referring to Diagrams I, II, III, IV and V, the area of cutaneous sensory loss on the dorsum of the hand is very variable in extent and shape; not only so, but it is in all these cases strikingly smaller than the “anatomical” area supplied by the radial nerve—very much smaller than one would expect to be explicable on the ground of ulnar or median overlapping. Indeed, as we have seen, it is in the majority of cases of musculospiral division in the lower third of the arm, if not in all, entirely absent. That this is not due to ulnar overlapping is made obvious by a glance at Diagrams I and V.

The explanation of this phenomenon lies in the fact that this area of skin “anatomically” associated in the mind with the radial
nerve, is really jointly supplied by at least two and sometimes by three different nerves—the radial, the musculocutaneous (posterior division) and sometimes also twigs of the inferior external cutaneous branch of the musculospiral. That this is so, is shown by a consideration of the facts with which we will be concerned in discussing the third set of variations in the sensory loss, as well as by the following:

(1) Wounds of the dorsal surface of the wrist dividing the radial and the posterior branch of the musculocutaneous, and in some cases fibres of the inferior external cutaneous branch of the musculospiral, produce a large area of sensory loss in this area, while (2) division of the radial nerve in the upper third of the forearm produces no loss of sensation in this area; (3) division of the radial nerve in the lower third of the forearm, after it has received a communicating branch from the posterior division of the musculocutaneous produces an area of sensory loss; (4) simultaneous section of the radial nerve and the posterior branch of the musculocutaneous, produces a smaller area of sensory loss than if the musculocutaneous and musculospiral in the upper third are cut.

Hence the variability in the extent of the sensory loss in these cases is evidently due to the fact that in some cases the musculospiral nerve supplies a larger, and the musculocutaneous a smaller area, whilst in others the opposite conditions obtain.

Variations in Position of the Area of Sensory Loss on the Dorsum of the Hand.—These variations in position, already noted, of the area of sensory loss, are probably due to this double—sometimes triple—supply of this particular area of the dorsum of the hand; where the loss lies to the outer side of the hand in musculospiral paresis most of the fibres of the latter nerve, including no doubt those of its inferior external cutaneous branch, probably supply this outer portion, whilst the majority of the musculocutaneous fibres pass to the inner portion, and where the loss lies more to the ulnar side the opposite conditions would again seem to occur.

Variations in the Proportion between Epicritic and Protopathic areas of Loss.—In this respect Sherren has described an apparently exactly similar phenomenon to that described in Case 4 and figured in Diagram IV as occurring as a result of simultaneous division of the radial and musculocutaneous nerves, viz., a dissociation of sensibility over a small area on the dorsum of the hand. He has ascribed this to the fibres of the inferior external cutaneous branch of the musculospiral supplying a greater area on
the dorsum of the hand with epicritic subserving fibres than that it supplies with protopathic, for, he writes, when the whole musculospiral is divided this dissociation of sensibility does not occur.

In Case 5, however, with complete division of the musculospiral this dissociation has occurred. Now in this case we have seen that the area of loss on the back of the forearm is very small. If this means that the inferior external cutaneous branch of the musculospiral is small, then most probably this nerve did not reach as far downwards as the wrist and fibres of it took no part in the innervation of the skin of the dorsum of the hand and hence did not have anything to do with the production of a dissociation of sensibility. In any case its fibres being divided with those of the main trunk of the nerve it could not have contributed to the production of this phenomenon, although since the musculocutaneous was intact, this does not mean that the inferior external cutaneous branch of the musculospiral does not always supply a larger area with epicritic than that it supplies with protopathic. This case, however, certainly tends to make one doubt the constancy of this arrangement.

Doubtless the explanation of this dissociation in Case 4 is, that in it the musculocutaneous fibres supply a larger area with epicritic than with protopathic sensibility, and the radial a larger with protopathic than with epicritic.

Hence we conclude that whilst this particular area of the skin of the hand is supplied by at least two and sometimes by three different nerves, section of one alone is insufficient to cause an area of sensory loss in it, Case 1 suggesting, however, that section of the radial—or lower third of the musculospiral—may in rare cases be an exception to this.

Moreover we must conclude that the proportion between the number of fibres subserving epicritic sensibility and the number subserving protopathic is not the same in each of the three paths by which such fibres may pass to the brachial plexus.