SUPPLEMENTARY MUSCLE MOVEMENTS IN PERIPHERAL NERVE LESIONS

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INTRODUCTION

The frequency with which more than one muscle may produce a similar movement of the segments about a joint emphasizes the necessity for the use of great care in the analysis of all muscle movements. This care is the more necessary in the study of peripheral nerve lesions because the muscles under consideration may receive their nerve supply from different sources.

The preservation of certain movements the loss of which is supposed to follow particular nerve lesions has been observed for many years. Sherren called attention to the fact that Swan, in 1834, was astonished at how much a rabbit could move its leg after experimental section of its sciatic nerve. Later Letievant studied this phenomenon and termed it supplementary motility. Since that time numerous investigators have observed its presence in peripheral nerve lesions. To Duchenne and Beevor we owe much of the present knowledge of these movements. Sherren, Head and Sherren, Claude, and Athanassio-Benisty are among the recent observers who noted its presence.

These movements may be caused by a number of factors. Among these may be included the anastomotic supply of muscles from adjacent nerves, movements produced by muscles other than primary movers in this action, movements occurring as the result of mechanical factors producing a change of direction of leverage by shortening and lengthening of tendons and muscles passing over several joints, and slight movements resulting from the recoil of elastic tissue following a movement in a direction opposite to the one desired.

2. Letievant: Traites des sections nerveuses, quoted by Sherren.
SUPPLEMENTARY MOVEMENTS IN MUSCULOSPITAL LESIONS

It is ordinarily understood that when the musculospiral nerve is divided there is lost, extension of the first phalanges of the fingers, extension of the wrist and of the thumb, adduction and abduction of the hand, and if the lesion is high, supination of the forearms when extended and, rarely, extension of the forearm.

The prime movers for extension of the distal phalanx of the thumb are the extensor longus pollicis, the abductor and adductor pollicis and the flexor brevis pollicis. Therefore, although never as complete or as strong as when the extensor longus pollicis is spared, the other muscles may produce extension of the distal phalanx of the thumb (Benisty) (Fig. 1).

A simulation of this movement may be produced by flexion of the distal phalanx of the thumb followed by relaxation. Such a mechanism is frequently observed in slight flexion of the fingers, in ulnar and median lesions, and flexion and extension of the toes in internal and external popliteal lesions, respectively.

If by abduction of the thumb is understood that movement which carries the thumb away from the first finger in a plane at right angles to the palm, then my observations agree with Beevor in that the extensor ossis metacarpi pollicis is a prime mover, along with the abductor pollicis, opponens pollicis and outer head of the flexor brevis pollicis. Although in musculospiral palsy the patient is unable to carry the thumb away from the first finger in a plane parallel to the palm, abduction is possible in a plane at right angles to the palm.

In a musculospiral palsy it is possible to tense the proximal phalanges of the fingers by extending the terminal phalanges; at the same
time flexion of the proximal ones occurs, as the result of the unopposed action of the lumbricales. Slight passive extension of the proximal phalanges may be produced by flexion of the hand at the wrist. Simulation of extension of the first phalanx of the index finger is frequently accomplished by strong adduction and opposition of the thumb against the first phalanx of the index finger, which is thereby passively lifted dorsally.

Normally, extension of the wrist is accomplished by the extensors carpi radialis and ulnaris, extensor longus pollicis, and sometimes by the extensor communis digitorum.

In a lesion of the musculospiral nerve below the elbow, paralysis of the extensors of the fingers may occur without involvement of the extensors of the wrist. Under these conditions the patient cannot extend the wrist if at the same time he attempts to extend the fingers,

![Fig. 2.—Wrist drop in musculospiral palsy.](http://archneurpsyc.jamanetwork.com/)

but if he flexes the fingers extension of the wrist may then be accomplished (Duchenne). To explain this we must recall the laws governing the action of muscles going over several joints. Beevor stated that "when a muscle by passing over two or more joints has two or more different actions, then if only one of these actions be required other muscles are brought into the movement whose actions are antagonistic to those of the muscles not required." These synergic muscles place the prime movers (in this instance being the extensors of the wrist) in the greatest elongation so as to augment their dynamic power and fix the joints so that the movements may be performed from a secure basis. Still another factor must be considered. Beevor has found that "if the movement of extending the wrist be performed with the fingers actively and fully extended, the extensors of the finger have to do all the work themselves and against the contraction of the flexors carpi
until the amount of work amounts to four or five pounds before the extensors carpi will join in and help them.” In the cited instance of paralysis of the extensors of the fingers with preservation of the extensors of the wrist, the extensors of the fingers cannot possibly reach the amount of pull which is necessary before the extensors of the wrist can be made to contract.

In a lesion of the musculospiral nerve with paralysis of the extensors of the wrist dorsiflexion of the hand may be produced by the action of muscles not innervated by the musculospiral nerve. Dorsiflexion of the hand may occur in the course of energetic con-

Fig. 3.—Passive extension of the wrist by flexion of the fingers.

Fig. 4.—Passive extension of the wrist by strong contraction of the pronator radii teres.

traction of the flexors of the fingers. This occurs under certain conditions and has been noted frequently (Benisty"). When the wrist-drop does not exceed an angle of 120 degrees complete flexion of the fingers produces extension at the wrist. In this condition the extensors of the wrist are shortened by contracture and fibrosis so that the angle between the hand and forearm is such that passive dorsi flexion, or dorsal dislocation of the hand occurs when complete flexion of the fingers is accomplished. Without this provision the fingers could not be completely closed because of the shortened extensor tendons. The
mechanism may be illustrated by using the wrist as a hinge, the hand as the weight, the flexors as the power transmitted through a pulley at the metacarpophalangeal joint to a fixed point at the origin of the extensors of the wrist (Figs. 2 and 3).

In some cases strong contraction of the pronator radii teres will produce extension of the hand on the forearm. During this movement the head of the radius is strongly depressed toward the palm, the styloid process of the ulna is pulled dorsally and the hand is deviated to the ulnar side. It can be demonstrated readily that the hand can be flexed to a greater degree when the forearm is supinated than pronated, and if flexed to its fullest degree when the forearm is supinated, the hand will be seen to extend when strong pronation is instituted. The extension at the wrist is probably due to two factors; first, lengthening of the extensor tendons and muscles, and second, to a leverage exerted on the scaphoid by the head of the radius (Figs. 2 and 4).

At times in addition to the contraction of the pronator, there is seen strong adduction and opposition of the thumb against the proximal phalanx of the index finger. At the same time resistance to this action
is made by the contraction of the lumbricale muscle, and the hand is extended on the forearm to a noticeable degree. During this action the middle, ring and little fingers show flexion at the proximal phalanx and extension of the two distal phalanges (Figs. 5 and 6). I have not found the last two mechanisms noted in literature.

Fig. 7.—Tensing of the flexors of the fingers when strong flexion of the proximal phalanges is performed.

Fig. 8.—Opposition of the thumb by the adductor pollicis and the flexor brevis pollicis.

Supination with the forearm extended is performed by the supinator brevis. The action of this muscle is superseded by the external rotators of the shoulder, chiefly the infraspinatus, which carry out a movement weakly suggestive of supination. With the forearm flexed
the biceps is the most powerful supinator and in musculospiral paralysis supination is unaffected in this position.

Although Duchenne\textsuperscript{3} contended that abduction and adduction of the wrist were performed by the extensors of the wrist alone, and Benisty\textsuperscript{7} stated that the action of the flexor carpi radialis as an abductor and of the flexor carpi ulnaris as an adductor is negligible, I believe, as does Beevor and also McKenzie,\textsuperscript{8} that for pure lateral movements the extensors and flexors are both necessary. Adduction and abduction of the wrist are superseded by pronation and supination of the forearm in the position of wrist-drop of a musculospiral palsy. If, however, the hand be passively extended to the same plane as that of

![Image](http://archneurpsyc.jamanetwork.com/)

**Fig. 9.—**Extension of the distal phalanges of the index and middle fingers in ulnar palsy.

the forearm, adduction accompanied by flexion of the wrist ensues as the result of contraction of the flexor carpi ulnaris, but I have not observed abduction to take place under the same conditions.

**MEDIAN NERVE LESIONS**

In a division of the median nerve it is supposed that the patient is unable to pronate the forearm, to tense the palm, to contract the flexor carpi radialis, to flex the second phalanges of any finger, to flex the distal or third phalanges of the index and middle fingers, to flex

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the proximal phalanges of the index and middle fingers, to flex the second phalanx of the thumb, to oppose or abduct the thumb, to fully flex the proximal phalanx of the thumb.

Supplementary movements to pronation have been described by Benisty, such as holding the elbow outward in flexion of the forearm, and rotating the arm inward in extension of the forearm.

Contraction of the palmar muscles and flexor carpi radialis cannot be supplemented.

Normally, flexion of the proximal phalanges is accomplished by the action of the lumbricales; flexion of the second phalanges by the flexor sublimis digitorum, and of the terminal phalanges by the flexor profundus digitorum. The flexor profundus digitorum for the two inner fingers, and the lumbricales for these fingers are supplied by the nerve.

Contrary to expectations, section of the median nerve frequently is followed by but little disturbance in the flexion of the proximal phalanges of the fingers. This seemingly paradoxical condition is due to a number of factors. Flexion of the proximal phalanges of the inner two fingers is preserved because the lumbricales of these two fingers are supplied by the ulnar nerve. The fact that the flexor profundus digitorum for the middle finger may in some instances receive its nerve supply from the ulnar, I think explains the frequent presence
of flexion of the first phalanx of that finger, inasmuch as the lumbricales have their origin in the tendon of the flexor profundus digitorum. If they are paralyzed, and especially if some contracture and shortening has taken place, contraction of the flexor profundus digitorum will produce a pull on the inert lumbricales and result in flexion of the proximal phalanx. That there is a pull exerted on the lumbricales seems to be shown by the fact that flexion of the first phalanx is stronger when combined with flexion of the terminal phalanges than when performed alone (Fig. 7). The lumbrical muscle for the middle finger likewise may receive its nerve supply from the ulnar. I am inclined to agree with McKenzie that the lumbricales flex the proximal phalanges and the interossei extend the distal phalanges of the fingers, under normal conditions. But as was seen to be the case with the flexors of the finger producing an extension of the hand, so under certain conditions the interossei may produce movements ordinarily subserved by the lumbricales. The interossei when extended produce a pull on the tendons of the flexors profundus and sublimis digitorum and when the lumbricales are paralyzed, especially if these are shortened, passive flexion of the proximal phalanges will occur. This mechanism permits full extension of the terminal phalanges, and in median nerve lesions occurs in the index and middle fingers. It is to be noted that despite the paralysis of the flexors in a median nerve lesion, the position of the fingers is one of flexion and not extension.

Flexion of the second phalanges of the inner two fingers occurs only a little weaker than normal as the result of the accompaniment of this movement to the normal flexion of the proximal and distal phalanges of these fingers. Flexion of the second phalanx of the middle
finger is frequently present in this general flexor movement. First, because it is influenced by flexion of the ring finger, and second, because the flexor sublimis digitorum for this finger in some instances must receive some of its nerve supply from the ulnar. Flexion of the terminal phalanx of the index finger is always absent. Flexion of the terminal phalanx of the middle finger may be present in those cases where the flexor profundus digitorum is supplied by the ulnar nerve.

Extension of the wrist produces slight passive flexion of the fingers which is better observed in combined lesions of the ulnar and median nerves.

Flexion of the terminal phalanx of the thumb may be simulated by the rebound following extension of this phalanx (Benisty).

Fig. 12.—Abduction of the index finger by extension of the thumb and its metacarpal bone.

Opposition of the thumb may be simulated by the action of the adductor pollicis and the action of the adductor pollicis and the inner head of the flexor brevis pollicis, with the terminal phalanges of the finger being opposed, flexed (Fig. 8).

ULNAR NERVE LESIONS

Section of the ulnar nerve produces inability to flex the proximal or distal phalanges of the ring and little fingers, to abduct or adduct the fingers, to extend the second and distal phalanges of any of the fingers, to adduct the thumb, to contract the flexor carpi ulnaris, to abduct or oppose the little finger.
Flexion of the distal and proximal phalanges of the ring and little fingers is performed by the two inner tendons of the flexor profundus digitorum and the two inner lumbricales, respectively. The imperfect flexion of these phalanges is the result of influence exerted on all segments when the flexor sublimis digitorum contracts. This is more marked in the little than in the ring finger.

Slight flexion of the proximal phalanx of the ring finger may be obtained from the contraction of the flexor profundus digitorum pulling on the lumbricales muscles which has part of its origin from the tendon of the profundus.

Although the interossei which extend the second and third phalanges of all fingers are paralyzed, inability to extend these phalanges in the index and middle fingers is rare (Fig. 9). Benisty\(^7\) attributes this to the preservation of the lumbricales, which she states extend the second and third phalanges, as do the interossei. With this McKenzie disagrees,

![Fig. 13.—Adduction of index finger by extensor indicis with hand in ulnar deviation.](http://archneurpsyc.jamanetwork.com/)

and he is inclined to believe that the dorsal interosseus for the index and middle fingers receive some of their nerve supply from the median. Beside this, he believes that with hyperextension of the proximal phalanx, there is an alteration in the line of pull of the interossei which become angular instead of straight, and that an extended proximal phalanx forms a rigid dorsal support for the sublimus tendon, thus increasing its flexion pull. Therefore, paralysis of the lumbricales alone would produce at one time overaction of flexion of the second phalanx and a poor mechanical principle for extension of the distal phalanges.

I have observed preservation of part of the first dorsal interosseus several days following a resection and suture of the ulnar nerve. This was demonstrated by a distinct bellying of the muscle accompanying the movement produced by its contraction. This leads me to believe
that there is a dual nerve supply for the first and second dorsal interossei. Other factors, however, enter into the production of extension of the second and third phalanges of the index and middle fingers. Duchenne, Benisty and McKenzie contend that the extensor communis digitorum does not produce extension of these phalanges. On the other hand, Beevor pointed out that although it was true that when the extensor digitorum was paralyzed the second and third phalanges could be extended, and when the interossei were paralyzed claw hand occurred and extension of the second and third phalanges was impossible, yet if in the latter case the first phalanges were passively flexed, the second and third phalanges could be extended. He says it is probable that in claw hand the inability of the extensor digitorum to extend the terminal phalanges is due to its energy being expended on the first phalanges which are not prevented from overextension by the lumbricales which are paralyzed. I have been able to verify this in many cases of ulnar and combined ulnar and median nerve lesions.

The following factors enter into preservation of extension of the second and third phalanges: Innervation of the first and second dorsal interossei by the median, passive extension of the second and third phalanges by flexion of the proximal ones, thereby shortening the interossei. If the interossei are paralyzed and the lumbricales preserved, the pull on the interossei is straight and not angular; under these conditions, contraction of the extensor communis digitorum may exert a pull on the inert interossei and produce extension of the second and third phalanges. Some pull on the interossei may be exerted by the extensor communis digitorum even if these conditions are absent, as may be seen in combined ulnar and median nerve lesions.

The fact that the extensor communis digitorum exerts a pull on the inert interossei does not mean that it is at all concerned with the

Fig. 14.—Position of wrist in combined ulnar and median lesion.
normal extension of the second and third phalanges which may be the result of an entirely independent contraction of the interossei.

In adduction of the thumb, as pointed out by Duchenne, the extensor longus pollicis is a prime mover, and in ulnar nerve lesions it may supplant the loss of the adductor pollicis (Fig. 10).

Abduction of the fingers away from the midline may result from forced extension of the first phalanges (Fig. 11). It is very marked in the index and little fingers. Slight adduction results from flexion of the first phalanges. Both of these movements have been known for a long time. The reason for the preservation of lateral movements in the middle and index fingers is given by Benisty as the preservation of their lumbricales, as well as the extensor action of the first phalanges.

As McKenzie points out, the lumbricales are not concerned with lateral movements of the fingers. The preservation of lateral movements of these two fingers is due in addition to the extensor movements of the first phalanges, to a dual nerve supply, as it has been noted on a number of occasions that the first dorsal interosseus is partially preserved in complete ulnar section. Beside the abduction observed in forced extension of the first phalanx, abduction movement of the index finger can be produced by strong contraction of the extensor ossei metacarpi pollicis and extensor brevis pollicis; the first dorsal interosseus having part of its origin on the metacarpal bone of the thumb, is pulled onward by extension of this bone and produces abduction of the index finger (Fig. 12). When the hand is adducted to the ulnar side, the tendon of

Fig. 15.—Flexion of the wrist by the extensor ossis metacarpi pollicis.
the extensor indicis is so deflected that its contraction produces slight adduction of the index finger (Fig. 13).

In combined lesions of the ulnar nerves, Duchenne\(^3\) has pointed out that the extensor ossei metacarpi pollicis is a flexor of the wrist (Figs. 14 and 15).

 SCIATIC NERVE LESIONS

In the lower extremity the principle supplementary movements have been observed in the toes as the result of rebound action following a movement in a direction opposite to the one intended.

In one case of a dissociated sciatic nerve lesion in which all the muscles supplied by this nerve with the exception of the flexors of the toes were paralyzed, strong flexion of the toes resulted in inversion and slight extension of the foot. The tibialis posticus was definitely paralyzed. This action was due to a mechanism similar to that observed in which strong flexion of the fingers produced passive extension of the hand musculospiral lesions.