MOVEMENTS OF THE THUMB IN RELATION TO PERIPHERAL NERVE INJURIES

V. C. MARSHALL, F.R.A.C.S.

R. D. MARSHALL, M.S.(Melb.), F.R.C.S., F.R.A.C.S.

Department of Surgery, University of Melbourne, Royal Melbourne Hospital, Parkville, Victoria, Australia

THE movements of the thumb are complex and the names of its muscles are confusing. Abductors may extend, abduct, or flex; flexors may flex, abduct, or oppose; and extensors may adduct as well as extend. Nerve injuries may further complicate the picture by paralysing isolated muscles. This paper is an attempt to clarify the situation.

In contrast to the other digits, the thumb has an extremely free range of movement, and yet is a strong and stable structure. This is possible because it is well supplied with muscles which support the carpo-metacarpal joint.

Little wonder, then, that when we come to consider its functional anatomy, we are confronted with a complicated mechanism from which it is difficult to sort out the components. The role of each muscle (and, more fundamental still, that of its nerve of supply) can often best be observed *in absentia*, when it is paralysed following a nerve injury. However, the efforts of other muscles to cover up and to compensate for any resultant disability tend to obscure the truth.

It is not surprising, therefore, that undergraduates experience considerable difficulty in analysing the movements of the thumb when they are trying to elicit signs of peripheral nerve injury in the hand. We suspect that similar difficulties may plague their more senior surgical colleagues.

In this paper we have no original observations to make. It is our aim only to analyse the normal movements of the thumb as an introduction to better understanding of the disability which results when there is injury to the median, ulnar or radial nerve.

The Anatomy of the Thumb *Carpometacarpal Joint*

This is a saddle-shaped synovial joint, with reciprocally curved articular surfaces, surrounded by a thick, loose, capsular ligament. It is completely separate from the other carpo-metacarpal joints, and possesses a far greater degree of mobility. There are thickenings in the capsule laterally, anteriorly, and posteriorly. The anterior and posterior ligamentous thickenings converge in their passage from the trapezium to the ulnar side of the first metacarpal. The configuration of the joint surfaces, and the ligamentous and muscular attachments, make it impossible for flexion-

extension movements to occur without axial rotation of the digit.

Thumb Musculature

The intrinsic muscles are the abductor pollicis brevis, flexor pollicis brevis (superficial and deep heads), opponens pollicis, adductor pollicis, 1st palmar interosseous, and 1st dorsal interosseous. The extrinsic muscles are the long flexor and extensor, the short extensor and the long abductor.

Points worthy of emphasis are:

(a) The abductor brevis and the superficial head of the flexor brevis form a smooth swelling, making up the visible part of the thenar eminence. They arise partly from the carpal bones, but mainly from the flexor retinaculum, and insert into the radial sesamoid of the metacarpo-phalangeal joint (Fig. 1). Usually both are supplied by the median nerve. The superficial head of flexor pollicis brevis is usually a small muscular slip, which will obviously have almost the same action as the short abductor, except that its situation on the ulnar side of the larger muscle enables it more easily to act as a flexor of the metacarpo-phalangeal joint.

(b) Opponens pollicis lies deep to these two muscles, and inserts into the radial aspect of the metacarpal shaft; its action is thus entirely on the carpo-metacarpal joint (Fig. 2).

(c) Both the transverse and oblique parts of the adductor pollicis insert into the ulnar sesamoid of the metacarpo-phalangeal joint. The first palmar interosseous muscle (which is sometimes erroneously called the deep head of flexor pollicis brevis), is a small slip running from the first metacarpal base to the ulnar sesamoid of the metacarpo-phalangeal joint. It is comparable to, but smaller than, the other palmar interosseous (Fig. 3). The adductor and first palmar interosseous are supplied by the ulnar nerve. A further muscle slip arising from the carpus, more or less blended initially with the oblique adductor mass, passes deep to the tendon of flexor pollicis longus, across to the radial sesamoid of the metacarpo-phalangeal joint (Fig. 2). It is usually supplied by the ulnar nerve. It matters little whether this is called a portion of adductor pollicis, or the deep head of flexor pollicis brevis, but it is important to realize that a muscle slip normally innervated by

FIG. 1.—The superficial thumb muscles, the short abductor and flexor, and the transverse and oblique adductor.

FIG. 2.—The short abductor and flexor removed, showing the opponens, the transverse and oblique adductor, and the ulnar innervated slip running deep to the long flexor tendon across to the radial sesamoid (deep head of flexor pollicis brevis).

the ulnar nerve passes to the radial side of the proximal phalanx.

Movements of the Thumb and the Muscles Involved

The configuration of the carpo-metacarpal joint, and the position of the thumb in a different plane from the other fingers, cause confusion in describing movements of the thumb.

In the position of rest (which might well be called the physiological position) the plane of the

FIG. 3.—The interossei (opponens removed).

thumb-nail is at right angles to the other nails, and its ulnar border is adjacent to the palmar surface of the index finger. If the thumb is pulled back in a dorsal direction to its fullest extent, the nail is seen to rotate so that it is now almost in the same plane as that of the other digits. This is the arbitrary 'anatomical position' which British anatomists have always used as the starting point in describing thumb movements. If the thumb is brought across the palm in the movement of 'opposition' to meet the pad of the little finger, the thumb-nail is seen to be rotated through almost 180°, so that the pads of the thumb and little finger meet. This may be designated the 'opposed position'.

Radial abduction of the thumb, denoting divergence from the other fingers radially in the plane of the palm, and palmar abduction, denoting movement away from the other fingers in a plane at right angles to the palm, are terms sanctioned by wide usage. Other anatomists have classed radial abduction as extension, and it is for this reason that abductor pollicis longus used to be called extensor ossis metacarpi pollicis.

We have a clear picture of flexion and extension in the other digits, and abduction and adduction entail respectively movements from and towards medius. Applying this to the thumb, and remembering that flexion and extension do not occur without rotation of the metacarpal on the carpus (and this is due to the joint itself, not to the attachment of muscles), a logical nomenclature arises.

Flexion is always accompanied by internal rotation, and extension by external rotation. Flexion (and extension) of the thumb is seen to occur, through a curved plane, from a point where the thumb is in the same plane as the other fingers, to the point of full 'opposition' where it has rotated

FIG. 4.—Cross-section through the metacarpal heads showing locus of movement of the thumb metacarpal (stippled area):
(1a) 'Anatomical' position.
(1b) Position of rest or 'physiological' position.
(1c) 'Opposed' position.
The range of thumb movement is further increased by movement at the metacarpo-phalangeal joint.

FIG. 5A.—The anatomical position.

medially through almost 180° . At any point along this line movement of the thumb at right-angles to the curve can occur; abduction being away from the other fingers, and adduction being towards the other fingers. This is illustrated in Fig. 4 which is a cross section through the metacarpal heads.

The range of movement of the thumb is limited by tension of the ligaments and muscles, and also by tension of the skin of the first web and of the thenar eminence, as is well seen in full abduction at right angles to the palm when tightness and creasing of the skin over the metacarpal head and thenar eminence occur.

It is important to realize that the names of the muscles cannot tally completely with the movements of flexion, extension, abduction and adduction. The line of action of a given muscle usually moves the thumb in a single direction. However, because of the inbuilt rotating action of the thumb metacarpal, dependent directly on the joint, this single direction may have a different description from point to point in the locus of thumb movements.

Thus, abductor pollicis longus produces a radial divergence of the thumb from the other fingers and this is correctly called abduction if the starting point is the anatomical position (Fig. 5a). How-

FIG. 5B.—The physiological position.

Metacarpal rotation occurs during the arc of opposition, so that abductor pollicis longus changes from an abductor to an extensor, and the thenar muscles from flexors to abductors.

ever, if the starting point is the physiological position (Fig. 5b), the movement is extension.

Similarly abductor pollicis brevis produces movement of the thumb in a line away from the palm. It thus acts as a flexor from the anatomical position (Fig. 5a), and as an abductor from the physiological position (Fig. 5b).

Extensor pollicis longus, from its point of angulation around the posterior radial tubercle, will pull the thumb dorsally from the physiological position, acting as an extensor. It has, however, an additional and quite powerful action of adducting the thumb from a position of radial divergence (see below).

Adductor pollicis is the prime mover in adduction from both the anatomical and physiological positions. It will also, however, in company with the short abductor, initiate flexion from the anatomical position (Fig. 5a). A list of the muscles producing movements follows, those contributing but slightly being enclosed in brackets; however

all that is required in practice is a knowledge of what each individual muscle can do, which is only possible if the peculiarities of the carpo-metacarpal joint are appreciated.

Muscles Producing Thumb Movements

The Arc of Flexion

Flexor pollicis brevis (both heads)
Abductor pollicis brevis
Opponens pollicis
Flexor pollicis longus
(Adductor pollicis)

The Arc of Extension

Extensor pollicis longus
Extensor pollicis brevis
Abductor pollicis longus

Abduction

(i) In the plane of the palm (or radial abduction from the anatomical position).

Abductor pollicis longus
Extensor pollicis brevis

(ii) Away from the plane of the palm inside the radial margin of the index finger (or palmar abduction from the physiological position).

Abductor pollicis brevis
Flexor pollicis brevis (both heads)
(Opponens pollicis)

(Abductor pollicis longus by means of a slip to abductor pollicis brevis can on occasion impart a few degrees of true palmar abduction, but attempts to increase the range immediately result in radial abduction of the thumb.)

Adduction

(i) In the plane of the palm (ulnar adduction).
Adductor pollicis

Extensor pollicis longus
1st palmar interosseous
(1st dorsal interosseous)

(ii) In the plane at right angles to the palm (palmar adduction).

Adductor pollicis
Extensor pollicis longus
(1st palmar interosseous)
(1st dorsal interosseous)

'Opposition'

This movement is, in fact, the movement of full flexion of the carpo-metacarpal joint of the thumb as previously described, in which the thumb is carried out from the palm and as far as possible towards the little finger. The placing of the pads of the thumb and little finger together depends on the thumb movement (flexion) and on reciprocal flexion of the little finger. It would be better if the name 'opponens pollicis'

were discarded for a muscle which is virtually a pure flexor of the carpo-metacarpal joint, as it implies falsely a major importance of this muscle in the action of 'opposition'. In summary, it is clear that the source of confusion with the nomenclature of the thenar muscles rests in our determination to describe joint movements with such terms as abduction-adduction, and flexion-extension, even if the corresponding movements do not exist. The fact is that no simple movement in a single plane can occur in the joint at the base of the thumb.

The Effects of Nerve Lesions

We shall now consider the deformities in ulnar, median and radial nerve lesions and the expected loss of movements. Trick movements due to compensation by unparalysed muscles are readily appreciated if the functional anatomy is kept in mind.

One is concerned here with the fully developed picture seen several weeks after a nerve lesion, when wasting and deformity have reached their peak. The recent nerve injury does not produce these effects, since the muscles retain their bulk, and the position of rest remains normal because of the elasticity of the muscle bellies. Thus immediately after a complete median nerve lesion the thumb will spring back to the position of rest if it is forcibly adducted and then all the muscles are relaxed. This can easily be misconstrued as active abduction if the thenar muscles are not palpated during the performance of the movement. A month later, the thenar eminence is wasted, the thumb has assumed the 'ape-like' position, and the loss of palmar abduction is obvious and complete, apart from trick movements to be considered.

Ulnar Nerve Palsy

The thumb muscles paralysed are the first dorsal and first palmar interossei, the adductor pollicis and the deep head of flexor pollicis brevis. Wasting of the adductor pollicis and first dorsal interosseous causes hollowing of the web between thumb and index. Disability of adduction would be expected, and is the basis of tests of ulnar nerve function. However, in practice compensation for loss of the adductor is often seen as adduction can be performed from a position of palmar or radial abduction by extensor pollicis longus. Movement of the thumb across the palm towards the little finger can then be continued by flexor pollicis longus, which simultaneously flexes the terminal phalanx. In any test of adduction, therefore, the tendon of extensor pollicis longus and the position of the terminal phalanx should be carefully observed.

FIG. 6.—Ulnar nerve palsy: Froment's sign positive.

FIG. 7.—Left ulnar nerve palsy. Froment's sign negative. Note prominence of tendon of extensor pollicis longus.

Froment's Sign

This is based upon the compensatory action of flexor pollicis longus in ulnar adduction of the thumb. A piece of paper is held against resistance between the straight thumb and the radial margin of the index finger and palm. Flexion of the terminal joint of the thumb by flexor pollicis longus so that the paper is held by a pincer action is a sign of failure of the adductor to perform the action (Fig. 6). However, extensor pollicis longus acting alone may provide firm adduction so that flexion of the interphalangeal joint does not occur, and under these circumstances the adductor pollicis may be thought to be functioning unless the tendon of extensor pollicis longus is observed and palpated during the performance of the test (Fig. 7).

Opposition of the Thumb and Little Finger

Normal opposition is a combination of the full movement of flexion and internal rotation of the thumb, and flexion of the little finger at the metacarpo-phalangeal joint, aided by cupping of the palm and a forward elevation of the relatively mobile fifth metacarpal head by the hypothenar muscles. It is customarily tested by placing the pads of the digits in contact, with the thumb and little finger extended at the interphalangeal joints (Fig. 8).

In ulnar nerve palsy the thumb component of the movement can be carried out adequately in the absence of the adductor by the median innervated short abductor and flexor, opponens and flexor pollicis longus. The little finger is unable, however, to reciprocate, and the hypothenar paralysis prevents the necessary elevation of the fifth metacarpal head. The thumb compensates for this by full flexion of the terminal phalanx which may enable it to contact the side of the terminal phalanx of the flexed and abducted little finger (Fig. 9). Sunderland (1944a) has pointed out that the flatness of the knuckles in opposition due to the failure of elevation of the fifth metacarpal head contrasts with the cupping of normal opposition and is an excellent test of ulnar paralysis. The test is best viewed from the dorsal or end-on aspect.

Median Nerve Palsy

Inspection may reveal the so-called 'simian hand', the thumb being pulled into extension and external rotation by the unopposed action of abductor pollicis longus and extensor pollicis longus and brevis. Muscle wasting causes flattening of the thenar eminence, crinkling of the skin and prominence of the first metacarpal shaft (Fig. 10).

FIG. 8.—Normal opposition.

Abduction of the Thumb at Right Angles to the Palm

This is the most useful test for median nerve palsy, and should always be tested against resistance from the physiological position, with the thumb inside the radial margin of the palm and index finger. We have seen that the slip from abductor pollicis longus to abductor pollicis brevis may give a weak palmar abduction from the anatomical position but this should not cause confusion if the test is performed as above.

Palmar abduction in median nerve palsy depends on the following:

(a) The size of the ulnar-innervated slip to the radial sesamoid (deep head of flexor pollicis brevis). This will hypertrophy in long-standing cases and may stand out as a visible ridge. It can cause weak palmar abduction and internal rotation.

(b) Anomalous innervation of the thenar musculature by the ulnar nerve. Clinical and anatomical studies have suggested (Sunderland and Hughes, 1946; Clifton, 1948; Rowntree, 1949) that anomalous

FIG. 9.—Opposition in ulnar nerve palsy. Note failure of little finger component.

lous innervation is relatively frequent, and that only in about 85% of cases does the normal distribution prevail. Sparing of the thenar muscles in median nerve palsies may be found in about 4% of hands, and sparing of the muscles usually innervated by the ulnar nerve in about 3% of hands in ulnar nerve palsies (Clifton, 1948). Confirmation of anomalies may be obtained by electrical stimulation or blocking of the suspected nerve of innervation.

Opposition of the Thumb and Little Finger

The full sweep of flexion and internal rotation of the thumb requires the action of median-innervated muscles. 'Pseudo-opposition' occurs characteristically in median nerve palsies—the bent thumb is swept straight across the palm by adductor pollicis and meets the side of the flexed terminal phalanx of the little finger (Fig. 11). However, opposition may be *normally* carried out in median nerve palsies in cases of ulnar innerva-

FIG. 10.—Median nerve palsy showing thenar atrophy.

tion of the short abductor and flexor, or *opponens pollicis*.

Flexion of Terminal Phalanx of the Thumb

Flexor pollicis longus is paralysed in a high median nerve palsy. The test is valid only if it is carried out against resistance in the position of rest, with the thumb inside the margin of the index finger and palm, and with the wrist in neutral position.

Trick flexion is produced by hyperextension of the wrist and full radial abduction of the thumb so that the stretched tendon of *flexor pollicis longus* causes passive flexion (Sunderland, 1944b), or by hyperextension and abduction of the thumb followed by sudden relaxation of the extensors causing rebound flexion (Wood Jones, 1949).

Combined Median and Ulnar Nerve Palsy

All thumb muscles are paralysed apart from the long abductor and extensor, and the short exten-

FIG. 11.—Median nerve palsy—attempted opposition.

sor. However, the previous remarks concerning Froment's sign apply, as *extensor pollicis longus* is still capable of adduction from a position of radial divergence, and a weak degree of abduction away from the palm may be produced by the slip from *abductor pollicis longus* to the short muscles.

Radial or Posterior Interosseous Nerve Palsy

The thumb muscles paralysed are the long and short extensor and long abductor. The thumb lies in the position of rest and flexion and opposition movements are normally carried out, but the thumb cannot be extended and radially abducted away from the margin of the index finger. Extension of the terminal phalanx of the thumb may be simulated by passive rebound from the flexed position (Fig. 12a and b), but if the movement is tested against resistance lack of function will be obvious.

Summary

Some points in relation to the anatomy of the carpo-metacarpal joint and thenar musculature are discussed. It is stressed that flexion and extension

FIG. 12A

FIG. 12B

Posterior interosseous nerve palsy—extension of terminal phalanx of thumb simulated by rebound.

are always accompanied by axial rotation of the digit, and a nomenclature of thumb movements is described. Because of rotation of the thumb during flexion-extension, the movement produced by an individual muscle will have a varying description from point to point throughout the range of thumb movement.

The effects of thumb paralysis in peripheral nerve palsies are considered. Compensatory action of unparalysed muscles may cause difficulty in

interpretation of tests of nerve function unless the anatomy of thumb movements is clearly appreciated.

We are grateful to Mr. D. H. Patey and Mr. L. P. Le Quesne, Department of Surgical Studies, Middlesex Hospital, for permission to study their patients, and to Professor M. R. Ewing, Professor of Surgery, University of Melbourne, for advice in the preparation of this paper.

REFERENCES

- CLIFTON, E. E. (1948): Unusual Innervation of the Intrinsic Muscles of the Hand by Median and Ulnar Nerve, *Surgery*, **23**, 12.
- ROWNTREE, T. (1949): Anomalous Innervation of the Hand Muscles, *J. Bone Jt Surg.*, **31B**, 505.
- SUNDERLAND, S. (1944a): The Significance of Hypothenar Elevation in Movements of Opposition of the Thumb, *Aust. N.Z.J. Surg.*, **13**, 155.
- (1944b): Flexion of the Distal Phalanx of the Thumb in Lesions of the Median Nerve, *Ibid.*, **13**, 157.
- , and HUGHES, E. S. R. (1946): Metrical and Non-metrical Features of the Muscular Branches of the Ulnar Nerve, *J. comp. Neurol.*, **85**, 113.
- WOOD JONES, F. (1949): 'The Principles of Anatomy as Seen in the Hand', Second Edition, p. 222. London: Bailliere, Tindall and Cox.