The Anterior Interosseous-Nerve Syndrome

WITH SPECIAL ATTENTION TO ITS VARIATIONS

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Since Kiloh and Nevin 11 described isolated neuritis of the anterior interosseous nerve, Seyffarth 12, Bell and Goldner 2, Thomas 25, Warren 27, Fearn and Good fellow 6, Stern, Rosner, and Blinder 23, Farber and Bryan 5, Sharrard 21, and Vichare 30 have all made contributions to the understanding of the subject. These papers described a total of nineteen cases. Among the earlier publications, those of Borchardt and Wjasmenski 4, Ranschburg 14, Wilson 22, and Parsonage and Turner 8 are to be noted.

![FIG. 1](image)

The right hand has an anterior interosseous-nerve paralysis. The pinch attitude of this hand is characteristic of this paralysis (see text).

This paper reports on ten new cases of anterior interosseous-nerve paralysis collected during a fourteen-year period, describes the typical pattern of this entity along with variants of the syndrome, and offers probable anatomical explanation for these clinical variations.

A presumptive diagnosis of anterior interosseous-nerve paralysis can be made from the attitude of the thumb and index finger during pinch (Fig. 1). Normally there are varying degrees of flexion of all joints of the thumb and index finger. With anterior interosseous paralysis the index finger shows extension of the distal interphalangeal joint and increased flexion of the proximal interphalangeal joint.

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The involved thumb reveals increased flexion of the metacarpophalangeal joint and hyperextension of the interphalangeal joint. In addition, the pulp contact between the thumb and index finger is abnormal, the area of contact of the pulp of the thumb with the index finger being much more proximal than normal.

Confirmatory findings are lack of function of the long flexors of the thumb and index and long fingers as well as lack of function of the pronator quadratus of the forearm—all changes which result from localized paralysis of the anterior interosseous nerve. There are also no sensory abnormalities or involvement of other muscles supplied by the main median-nerve trunk.

With the common distribution of the median nerve the superficial flexors, lumbricals, thenar muscles, and the deep flexors to the ring and little fingers are normal. In the extreme “all median hand” the anterior interosseous nerve supplies all of the profundus. Accordingly in this and the other variants of the median nerve, the attitude of the thumb and index finger in the pinch position would be the same as described but there would be weakness or paralysis of some or all of the components of the flexor digitorum profundus.

Conversely, when the ulnar nerve innervates more of the profundus, the long-finger profundus is unaffected or is only partially paralyzed by loss of function of the anterior interosseous nerve. Here too, the involved hand would have the same pinch attitude as described but the flexor profundus of the long finger would be weak or

**Fig. 2**

Left forearm specimen. Note the multiple branches of the motor nerve to the flexor pollicis longus (FPL) entering the muscle proximally. The forceps is beneath a tendinous origin of the flexor superficialis.
normal. Sunderland observed that the portion of the flexor digitorum profundus serving the index finger is the only part of this muscle that is exclusively and constantly supplied by the median nerve. If the ulnar nerve did supply the entire flexor profundus group of muscles, then paralysis of the anterior interosseous nerve would be manifest only by lack of flexion of the interphalangeal joint of the thumb and paralysis of the pronator quadratus. One such rare case was recently reported by Sunderland 27.

In testing for the function of the pronator quadratus, one must eliminate the rotatory action of the pronator teres on the forearm by fully flexing the elbow. Since the pronator teres usually has two heads, the humeral head can be made ineffective by elbow flexion so that only about 25 per cent of the muscle's prontorv strength from the ulnar head remains. In this position, if there is paralysis of the pronator quadratus, there will be very weak resistance to forced supination of the forearm, whereas if the pronator quadratus is not paralyzed, resistance to supination will be normal when the elbow is flexed or extended. When the pronator teres has no ulnar head, a variation found in 9 per cent of limbs, there will be at most only a trace of active pronation in the presence of anterior interosseous-nerve paralysis when the elbow is fully flexed. The clinical evaluation of the function of the pronator quadratus can be corroborated by direct electrical stimulation of the muscle.

Anatomical Features

The anterior interosseous nerve arises from the median nerve five to eight

![Image](https://example.com/image.png)
Anterior Interosseous-Nerve Syndrome

Right forearm specimen. Note the Martin-Gruber type communication between the median nerve and ulnar nerve through a branch of the anterior interosseous nerve. The ulnar origin of the flexor digitorum profundus muscle usually innervates three muscles, the flexor pollicis longus, the radial half of the flexor digitorum profundus, and the pronator quadratus. At the end of its passage it supplies sensory fibers to the radiocarpal, intercarpal, carpometacarpal, digit, and distal radio-ulnar joints.

I made detailed anatomical studies of twenty-five forearms with particular attention to the branching of the anterior interosseous nerve in an attempt to explain an unusual isolated paralysis of the flexor pollicis longus in this syndrome (Cases 1, 9, and 10). The motor branch of the flexor pollicis longus muscle usually arises from the interosseous nerve approximately four centimeters distal to its origin from the main median-nerve trunk. The motor branch promptly divides into three or four branches and enters the proximal end of the muscle on its medial
border in close proximity to the radius (Fig. 2). Near its site of origin the motor branch is vulnerable to injury or to compression by a tendinous origin of the flexor superficialis to the long finger. In addition since it is crossed by collateral vessels of the anterior interosseous artery, thrombosis of these vessels may cause dysfunction (Fig. 3). Finally the pollicis motor branch is vulnerable to injury during open reduction of fractures of the middle third of the radius if the dissection is extra-periosteal.

In connection with this syndrome it is important to remember that a Martin-Gruber type of communication between the median and ulnar nerves occurs in 15 per cent of limbs (Fig. 4), and that half of these communications, according to Thomson, arise from the anterior interosseous nerve. This communication between the median and ulnar nerves is of significance because the anastomosing fibers carry the motor innervation of several of the intrinsic muscles of the hand. Mannerfelt demonstrated that these crossing fibers may innervate the first dorsal interosseous, adductor pollicis, and probably the abductor digitii quinti. Morrison and I confirmed Mannerfelt’s observations by electrical methods. In addition to the intrinsic muscles previously mentioned the second and third dorsal interosseous muscles were also found to be supplied by these crossing fibers in some limbs. Thus, a patient with a full-blown anterior interosseous-nerve paralysis may have not only the usual dysfunction of the deep flexors of the thumb and the index and long fingers and the pronator quadratus but also paralysis of some intrinsic muscles of the hand. Such a communication is a not too infrequent anatomical variation.

Illustrative Cases

Case 1. On July 15, 1959, a female bank teller, twenty-four years old, noted sudden pain across the anterior aspect of her left thumb and the lower part of her forearm after lifting an extremely heavy bag of coins. Shortly thereafter she noted that she could not flex the tip of her thumb. A presumptive diagnosis of rupture of the flexor pollicis longus was made. Six months after injury,
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Illustrative Cases

CASE 1. On July 15, 1939, a female bank teller, twenty-four years old, noted sudden pain across the anterior aspect of her left thumb and the lower part of her forearm after lifting an extremely heavy bag of coins. Shortly thereafter she noted that she could not flex the tip of her thumb. A presumptive diagnosis of rupture of the flexor pollicis longus was made. Six months after injury,
An electromyogram revealed fibrillations in the pronator quadratus and the flexor pollicis longus.

Exploration of the median nerve was performed on April 29, 1968. The median nerve was identified proximal to the lacertus fibrosus and was traced through the pronator teres, where it passed between the two heads of the muscle. There were adhesions between the median nerve and the deep head. When these were cleared, a distinct tendinous origin to the deep head of the pronator teres was found. After this deep tendinous origin of the pronator teres was severed and an internal neurolysis of the anterior interosseous nerve was performed by injecting normal saline, the vessels on the surface of the median nerve filled with blood and became visible.

The limb was immobilized in a cast for three weeks postoperatively. Within a few days, function returned to the flexor profundus of the index finger. At three weeks contraction of the flexor pollicis longus was evident. By the sixth postoperative week there was normal power in the flexor pollicis longus, flexor profundus of the index finger, and the pronator quadratus.

The biopsy report of the specimen of the tendon of the deep head of the pronator teres tendon was non-specific tendinitis.
The recovery pattern of the patient after neurolysis suggests that the nerve lesion was a mixed neuropraxia and axonotmesis. The prompt return of full function to the paretic flexor profundus to the index finger is indicative of neuropraxia. The fibrillations and delayed recovery in the flexor pollicis longus and pronator quadratus suggest axonotmesis with Wallerian degeneration.

CASE 3: A Puerto Rican man, twenty-seven years old, sustained multiple small lacerations of the proximal one-third of the right forearm. When the patient was first seen on July 25, 1968, four weeks after injury, he was unable to flex the thumb and index finger. Sensation was intact throughout the hand. There was paralysis of the flexor pollicis longus, flexor profundus to the index finger, and the pronator quadratus. In addition there was some weakness of the flexor superficialis to the long and ring fingers. Electromyography performed at this time revealed fibrillations in all the muscles innervated by the anterior interosseous nerve and in part of the flexor superficialis.

![Anterior](image)

**Fig. 8**

**Anterior**

On August 7, 1968, six weeks after injury, exploration of the median nerve in the proximal part of the forearm revealed a neuroma on the posterior aspect of the nerve (Fig. 7) about two centimeters proximal to the origin of the anterior interosseous nerve. Since the interosseous nerve becomes a separate bundle approximately 2.5 centimeters proximal to its departure from the main trunk of the median nerve at a point 224 to 234 millimeters proximal to the radial styloid process (Fig. 6), the bundles of the median nerve were teased out in an effort to remove the neuroma and repair the damaged fasciculus. However, when the bundles involved in neuroma were identified and electrically stimulated proximally, there was a definite response in the flexor superficialis muscles. Even though the lesion was firm and grossly appeared to resemble a non-functioning neuroma, it was not excised in order not to weaken the active muscles of the hand or lose some critical median-sensation. Instead, the tourniquet was released for twenty minutes. It was then reinfibulated and the entire brachioradialis compartment was opened through the proximal incision. A separate longitudinal curved volar incision was made at the wrist, and the brachioradialis tendon was transferred to the flexor pollicis longus tendon. In addition the tendon of the flexor profundus to the index finger was severed at its musculotendinous junction and transferred to the tendon of the flexor profundus to the ring finger at proper tension. Postoperatively, the fingers, wrist, and forearm were immobilized with dorsal and volar splints holding the hand in a functional position for three weeks. The patient's sensation remained undisturbed. When the plaster splints were removed function was markedly improved and when last seen, eight weeks after operation, the patient...
could flex the pulp of the index finger to the distal palmar crease. The thumb could easily touch the index, long, and ring fingers with its interphalangeal joint flexed. The patient returned to work as a jeweler's apprentice.

Case 4. A man, thirty-three years old, was seen in June 1964, two months after a fall down a flight of stairs. He sustained multiple hematomas and contusions and his right forearm was swollen. He stated he could use his hand fully at first but about three to four weeks after the injury he noted weakness in his right hand and inability to grasp small objects in his fingers. The initial examination revealed a complete paralysis of the flexor pollicis longus, the flexor profundus to the index and long fingers, and the pronator quadratus. There were no sensory abnormalities and the other forearm and hand muscles were grossly normal. Electromyographic studies revealed fibrillations in the paralyzed muscles. The intrinsic muscles were not sampled.

In July 1964, surgical exposure of the two heads of the pronator teres revealed scarring of the fascia of the deep head and thrombosed vessels crossing the anterior interosseous nerve. These were released and internal neurolysis using saline was performed. Four weeks postoperatively, active motion of the interphalangeal joint of the thumb was seen at six weeks. Full function returned twelve weeks postoperatively. At follow-up three years later, the patient had a normal functioning hand.

The patient had a complete anterior interosseous-nerve lesion with axonotmesis as evidenced by the fibrillations and the recovery pattern.

Case 5. A twenty-four-year-old male plumber was first seen thirty months after onset of paralysis of the deep flexors to the thumb and index finger of the right hand. In December 1965 he was bending pipe when he noted sudden pain in the forearm. The following day he was unable to use his thumb and index finger as well. Electromyographic studies at that time were normal and a presumptive diagnosis of probable rupture of the deep flexors to the thumb and index finger was first noted. When he was ten years old he had sustained a penetrating wound of the proximal part of the right forearm that "went down to bone," but the wound healed without difficulty or complications.

Approximately fourteen months after his injury in 1965 he had regained some active movement of the terminal phalanges of the thumb and index fingers. Two and one-half years after onset he had moderate weakness of the flexor pollicis longus, the flexor profundus to the index finger, and the pronator quadratus.

Case 6. A twenty-eight-year-old male double bass player first noted weakness of the left thumb and index finger while playing his instrument the day before he was first examined. At that time he was unable to flex the terminal interphalangeal joint of the thumb and index finger. With no treatment except for rest of the extremity in a sling, full function returned three weeks after onset. At follow-up two years later the episode of weakness was continuing his musical career and had had no further trouble.

Case 7. A fifty-eight-year-old woman first noted pain in the proximal part of her forearm while she was carrying her heavy pocketbook suspended by a strap across this region. When she was first examined one week after the onset of pain, there was no pain or local tenderness in the arm, but she had paralysis of the flexor muscles of the terminal joint of the thumb and index finger. Spontaneous recovery occurred four to six weeks after onset. Six years later she had had no further difficulty.

Case 8. A twenty-two-year-old man noted weakness in his right thumb and index finger arising one morning. He recalled no specific injury. The paralysis of the flexor pollicis longus and flexor profundus to the index finger subsided over a three-week period. At follow-up examination, eighteen months after onset, there was no recurrence nor had any systemic disease developed that would explain his symptoms.

Case 9. An eighteen-year-old girl had an open reduction of a fracture of the mid-shaft of the right radius and fixation with a plate and screws in March 1961. When I first saw the patient nine months after operation, she was unable to flex the distal phalanx of the thumb; but other long flexors of the forearm and the pronator quadratus muscle were intact. The flexor pollicis longus did not respond to electrical stimulation of the median nerve or to direct stimulation in the region of the motor end plate. Transfer of the flexor superficialis of the ring finger to the flexor pollicis longus resulted in excellent function.

Case 10. A forty-six-year-old man had an open reduction and plate fixation of radial fracture.
The patient returned to work six months later, he was unable to flex the terminal joint of the thumb. There was no electrical evidence of returning function in the flexor pollicis longus. A transfer of the ring finger flexor superficialis was performed with subsequent return of full flexion of the thumb.

**Discussion**

There are significant variations in the anatomical relationship of the median nerve to the pronator teres. Knowledge of these variations is essential when one explores this region surgically. Beaton and Anson, reporting on 240 dissected limbs, found that the course of the median nerve was between the superficial and deep heads of the pronator teres in 82 per cent of limbs. In 9 per cent there was no bony head of the pronator teres. In 7 per cent the median nerve passed deep to the bony head. In 2 per cent the nerve passed through the humeral head of the pronator teres.

There are isolated reports of the median nerve passing anterior to the pronator teres. Because of these many variations, the best surgical approach when exploring the anterior interosseous nerve is to identify the median nerve proximal to the lacertus fibrosus and to trace it distally through the region of the pronator.

Based on the sixteen cases of anterior interosseous-nerve paralysis which I have observed, my detailed anatomical dissections, and a review of the nineteen cases reported in the literature, the following conclusions are suggested:

1. Patients who have spontaneous paralysis of the anterior interosseous nerve initially be treated by nonsurgical methods because many have a satisfactory return of function and no recurrence. However, if there is no sign of clinical or electromyographic improvement in six to eight weeks, exploration of the anterior interosseous nerve is indicated.

2. Patients who have had a penetrating wound of the forearm and have an injury to the anterior interosseous nerve or to the anterior-interosseous-fascicular component of the median nerve are best treated by primary exploration and repair, if the condition of the wound and the time elapsed since injury permit.

3. If the anterior interosseous nerve is irreparable, appropriate muscle transfers should be performed. The flexor superficialis of the ring finger is an excellent motor for the flexor pollicis longus tendon. The brachioradialis is a satisfactory substitute. The transfer of the distal portion of the flexor profundus tendon of the index finger to the functioning profundus tendon of the ring or long finger at the wrist can provide satisfactory flexion of the distal phalanx of the index finger.

4. There are variants of the syndrome. An isolated paralysis of the flexor pollicis longus can occur and must be differentiated from a rupture of the muscle itself. Some of the intrinsic muscles of the hand (especially the first dorsal interosseus, adductor pollicis, abductor digiti quinti, and the second and third dorsal interosseus) may show gross paralysis or partial electrical denervation in an anterior interosseous-nerve syndrome. The finding of intrinsic muscle involvement with paralysis of the long flexors of the thumb and the index and long fingers and of the pronator quadratus is not inconsistent with the diagnosis of injury to the anterior interosseous nerve in the proximal part of the forearm.

5. Finally, the anterior interosseous nerve and its branches are vulnerable to injury in open reduction of fractures of the midshaft of the radius and in the muscle-split procedure. Page 39, in his original description of the procedure, drew attention to this.

**Summary**

Ten new cases of paralysis of the interosseous nerve are described and the findings in these cases are correlated with anatomical studies and the findings previously reported in the literature.
The hand so paralyzed has a typical appearance with a characteristic disturbance of pinch. The clinical picture is as constant as that presented by other well known peripheral nerve injuries.

Recommendations for treatment are offered.

References

15. MORRISON, D. P., and SPINNER, MORTON: Unpublished data.