Surgical treatment and outcomes in 45 cases of posterior interosseous nerve entrapments and injuries

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Object. The authors report data in 45 surgically treated posterior interosseous nerve (PIN) entrapments or injuries.

Methods. Forty-five PIN entrapments or injuries were managed surgically between 1967 and 2004 at Louisiana State University Health Sciences Center (LSUHSC) or Stanford University Medical Center. Patient charts were reviewed retrospectively. The LSUHSC grading system was used to assess PIN-innervated muscle function.

Injuries were caused by nontraumatic (21 PIN entrapments and four tumors) and traumatic (nine lacerations, eight fractures, and three contusions) mechanisms. Presentations included weakness in the extensor carpi ulnaris muscle, causing compromised wrist extension and radial drift; extensor digitorum, indicis, and digitii minimi muscles with paretic finger extension; extensor pollicis brevis and longus muscles with weak thumb extension; and abductor pollicis longus muscle with rare decreased thumb abduction due to substitutions of the median nerve–innervated abductor pollicis brevis muscle and, at 90°, the extensor pollicis brevis and longus muscles. Preoperative evaluations consisted of electromyography and nerve conduction studies, elbow and forearm plain x-ray films, and magnetic resonance imaging for tumor detection.

At surgery, in continuity lesions were found in 21 entrapments and three fracture-related and three contusion injuries; all transmitted nerve action potentials (NAPs) and were treated with neurolysis. Five fracture-related PIN injuries, one of which was a lacerating injury, were in continuity and transmitted no NAPs; graft repairs were performed in all of these cases. Among nine lacerations, three PINs appeared in continuity, although intraoperative NAPs were absent. Two of these nerves were treated with secondary end-to-end suture anastomosis repair and one with secondary graft repair. There were six transected lacerations: three were treated with primary suture anastomosis repair, two with secondary suture anastomosis, and one with graft repair. Four tumors involving the PIN were resected. Most muscles innervated by 45 PINs had LSUHSC Grade 3 or better functional outcomes.

Conclusions. Forty-five PIN entrapments or injuries responded well to PIN release and/or repair.

KEY WORDS • supinator syndrome • arcade of Frohse • posterior interosseous nerve

The radial nerve branches in the forearm into the PIN and SSRN. Traditionally, the PIN supplies motor fibers to the ECU muscle, a wrist extensor; the finger extensors, that is, the extensor digitorum, indicis, and digitii minimi muscles; and the thumb extensors, which include the EPB and EPL muscles. The PIN also innervates the APL muscle, a thumb abductor. Sensory innervation to the dorsal wrist capsule and intercarpal ligaments, and the intercarpal and the carpometacarpal joints of the index, middle, and ring fingers is transmitted by the PIN as well.29

Thus, compression of the PIN causes weakness in wrist extension together with a radial drift, finger extension at the metacarpophalangeal joint, thumb extension, and thumb abduction. Thumb abduction is weak because there is a lack of EPB and EPL muscle strength to brace the thumb and allow the median nerve–innervated APB muscle and the PIN-innervated APL muscle to provide abstraction. It should also be emphasized that there is no wrist drop because of dual innervation of wrist extension by the PIN and the radial nerve; the latter nerve innervates the ECRL and ECRB muscles. The patient with PIN compression also presents with deep forearm pain and/or discomfort; there is no sensory deficit manifested in the forearm given preservation of the SSRN.

There are many possible sites and causes of PIN entrapment. The PIN syndrome, which is also called the “supinator syndrome” or “supinator entrapment syndrome,” is an infrequent compression neuropathy of the PIN at the arcade of Frohse, the most proximal portion of the superficial head of the supinator muscle. The proximal edge of the volar su-
Posterior interosseous nerve entrapments or injuries

Pinpointer muscle may be fibrous and can be the site of entrapment. Posterior interosseous nerve entrapment by the arcade of Frohse was first observed by Kopell and Thompson in 1963.

Compression of the PIN by intermuscular septa, fibrous bands, and muscle margins at areas other than the arcade of Frohse are well-known but very uncommon. For example, the site of the PIN’s exit from the supinator muscle was identified as another point of entrapment by Spinner in 1978 and Derkash and Niebauer in 1981. There has also been a report of PIN entrapment under the tendinous margin of the ECRB muscle. A bilateral PIN palsy caused by bilateral compression by both the arcade of Frohse and the vessels of the recurrent radial artery has been reported as well.

Radial tunnel syndrome is characterized as a disease separate from the supinator or PIN entrapment syndromes. Patients with RTS present with pain and tenderness in the region of the forearm at the site of the brachioradialis muscle, especially on deep palpation and on wrist flexion, dorsiflexion, pronation, or supination against pressure. In this syndrome the PIN is purportedly irritated; however, there is no measurable clinically or electromyographically demonstrated loss of function in that nerve’s distribution. The exact nature of this disorder remains unclear. Some authors believe the syndrome is caused by PIN compression within the radial tunnel formed by the musculoaponeurotic septa of the distal arm and proximal forearm. Others attribute the syndrome to intermittent, dynamic compression of the nerve associated with repeated pronation and supination.

The largest series on PIN palsies in the literature over the last 10 years was that by Kalb, et al., who reported on 110 patients with surgically treated PIN palsies. Riniker, et al., reported on a series of 79 surgically treated PIN compression neuropathies. Other large studies of PIN injury in the recent literature have included 40 patients surgically treated by Young, et al., in 1990 Cravens and Kline published data from 28 PIN palsies surgically treated at LSUHSC, which has been expanded in the present series. Hashizume, et al., have reported findings in 25 patients with surgically treated PIN injuries. Rinker, et al., have reported findings in 25 patients with surgically treated nontraumatic paralyses of the PIN; Barbato, et al., and Shergill, et al., have reported data on 20 and 18 PIN lesions, respectively.

One series in the literature from the last 10 years consisted solely of RTS cases. Orfaly reported follow-up data in 25 of 28 patients with RTS who had presented with pain but no weakness; among the 25 patients, 73% experienced pain relief after surgery.

In the present paper we report on 45 PIN injuries managed at LSUHSC or SUMC, representing a relatively large series. The treatment and operative techniques applied as well as the subsequent outcomes are presented.

Clinical Material and Methods

Background: PIN Injury

Anatomical Review. The radial nerve leaves the forearm flexor compartment by spiraling around the humerus and piercing the lateral intermuscular septum. It emerges from the intermuscular septum several inches above the lateral epicondyle and lies in a cleft between the proximal brachio-

radialis muscle and the lateral portion of the biceps and brachioradialis muscles, which is a good site to find the nerve and sometimes begin surgical dissection. The radial nerve then enters the antecubital fossa under the brachioradialis and ECRL muscles. If the brachioradialis muscle is retracted laterally, the direct forearm continuation of the radial nerve, the PIN, and SSRN branches can be seen (Fig. 1).

The branches to the ECRL and ECRB muscles may be partially hidden by the small vessels in this area. It is a commonly held belief that the ECRL muscle branches may arise from the distal whole radial nerve, proximal SSRN, or, less frequently, the proximal PIN. These findings have been challenged by data from several studies, however. In the majority of specimens in their cadaveric studies, Abrams, et al., observed that the nerve to the ECRL muscle originated from the PIN; in additional cadaveric studies, researchers found that the ECRB muscle arose from the proximal PIN, the radial nerve, or the SSRN. Thus, innervation of the common extensor muscle origins at the level of the PIN bifurcation is highly variable.

The supinator and ECU muscles are supplied by the PIN before the nerve passes between the heads of the supinator muscle. However, some authors have stated that the ECU muscle is supplied by later PIN branches rather than being innervated before the PIN enters between these two heads.

Knowledge of the anatomy of the two supinator muscle heads is key to an understanding of the PIN’s course. The superficial and deep heads of the supinator muscle both have origins from the lateral epicondyle of the humerus and ulna, and both insert into various aspects of the radius. The superficial head inserts into the lateral edge of the radial tuberosity and the oblique line of the radius. The upper border of the deep head of the supinator muscle runs at an approximate right angle to the course of the PIN. Thus, the deep head’s upper fibers encircle the radial neck above the tuberosity and attach to an area just short of the medial radial neck, while the remaining fibers insert into the dorsolateral surfaces of the radius body midway between the radial head and the oblique line.

The PIN begins its path by running beneath the proximal edge of the volar superficial head of the supinator muscle, which is sometimes fibrous and sometimes muscular (Fig. 2). Here it is surrounded by small arteries and veins, which usually cross the nerve transversely. The volar superficial head of the supinator muscle forms an arch or arcade around the PIN known as the arcade of Frohse. The PIN next passes between the superficial and deep heads of the supinator muscle, inclining posteroinferiorly in its course. After traveling under the distal border of the supinator muscle and deep to the superficial layer of extensor muscles, the PIN immediately breaks up into short, also called “recurrent” or “superficial,” branches, which supply the extensor musculature, that is, the extensor digitorum and extensor digiti minimi and, according to some authors, the ECU muscles. The PIN continues as two long, also termed “descending” or “deep,” motor branches; the medial of these branches supplies the extensor indicis and EPL muscles and the lateral descending branch, the EPB and APL muscles (Fig. 3).

Each of the three bones of the thumb receives one or more tendons on its dorsal surface: the EPB muscle and median nerve–innervated APB muscle to the proximal pha-
Fig. 1. Photograph depicting the radial nerve as it divides into two terminal branches, the superficial sensory radial nerve and the PIN. This division occurs as the radial nerve enters the forearm through the cubital fossa. At this location it lies under the brachioradialis and ECRL muscles. Proximal to the supinator muscle heads, the PIN branches supply the ECRB and supinator muscles. N. = nerve. Reprinted from Atlas of Peripheral Nerve Surgery, Kline DG, Hudson AR, Kim DH, p 255, copyright 2001, with permission from Elsevier.

Fig. 2. Photograph showing the PIN as it passes between the superficial and deep heads of the supinator muscle; the latter head appears in the right upper-extremity cadaveric specimen. The most proximal portion of the superficial head may be tendinous and form a fibrous arch known as the arcade of Frohse. This 1-cm arch is formed between the tip of the lateral epicondyle and the medial aspect of the lateral epicondyle, just lateral to the articular surface of the capitulum. Reprinted from Atlas of Peripheral Nerve Surgery, Kline DG, Hudson AR, Kim DH, p 255, copyright 2001, with permission from Elsevier.
lanx, the APL muscle to the metacarpal bone, and the EPL muscle to the distal phalanx. Three of these muscles—the EPB, EPL, and APL muscles—are supplied by the PIN branches and are affected in both radial nerve and PIN lesions. The APL muscle may act as a weak wrist flexor, and the APB muscle may weakly extend the thumb in the absence of EPL muscle function.

Clinical Features of PIN Syndrome. Patients in this series suffered the acute onset of a deep aching pain in the proximal forearm, which occasionally radiated into the shoulder and neck. Another symptom was a sense of heaviness in the arm followed by an inability to sleep on the affected side. Sensory disturbances were rare.

On examination of a patient with PIN palsy, there is on the application of light digital pressure a prominent localized tenderness over the radial nerve at the level of the proximal margin of the superficial head of the supinator muscle. This finding may accentuate the chief complaint. Supinator muscle stress against resistance may also reproduce the patient’s symptoms.

The innervation patterns of the terminal branches of the PIN are very complicated and inconsistent. Suematsu and Hirayama reported three types of nontraumatic PIN palsies. Type I is characterized by dropped fingers and thumb due to compression of the PIN’s recurrent and descending branches at the entrance point of the supinator muscle and/or within this muscle. Type II, involving dropped fingers, is caused by compression of the recurrent branch alone, and Type III, associated with a dropped thumb, is due to compression of one of the descending branches. Hirayama and Takemitsu have also reported on a patient with isolated paralysis of a descending branch of the PIN presenting with a dropped thumb but no weakness of the extensor indicis muscle. The exit point from the supinator muscle with nonuniformity of its distal musculotendinous membrane is considered to be the site and origin of varying compressions in Types II and III PIN paralysis.

Alternately, Hirachi, et al., summarized three types of presentations of traumatic PIN palsies. In their classification, Type I is a complete PIN palsy resulting in weak wrist extension together with a radial drift, loss in extension at the metacarpophalangeal joints of all the fingers and the thumb, and weak thumb abduction. Type II represents injury to a portion of the recurrent nerve branches, that is, a loss in extension of the little and ring fingers without loss in extension of the middle and index fingers and thumb. Type III consists of a loss in extension of the index finger and the thumb due to involvement of the descending branch of the median nerve and loss in abduction of the thumb without loss in extension of the other fingers. The latter is a result of the involvement of a portion of the lateral descending branches of the PIN, without involvement of the EPB muscle.

Another categorization scheme—that is, one for two distinct clinical syndromes characterized by differing locations of PIN compression or injury—includes PIN syndrome and RTS. Posterior interosseous nerve syndrome, as described, can be caused by a local compressive lesion, but can also be due to repetitive pronation and supination as well as proximal radius fractures. Patients with this complex present
with painless weakness in muscles innervated by the PIN without sensory loss. Poorly localized pain and dysesthesias may occasionally be present. When weakness is pronounced, unopposed action of the radial nerve–innervated ECRL muscle causes the hand to deviate radially at the wrist and the fingers to be flexed at the metacarpophalangeal joint. There is no wrist drop. An electromyography study can be used to differentiate this PIN syndrome from a partial radial nerve palsy.

Radial tunnel syndrome can also occur in patients who perform repetitive pronation and supination while either performing their job or playing racket sports. Radial tunnel syndrome is characterized by the insidious onset of poorly localized aching pain in the elbow and forearm. Weakness is not a feature, which is a differentiating characteristic between RTS and PIN syndrome. With RTS, there may be decreased sensation in the first dorsal web space. Radial tunnel syndrome may be confused or coexist with lateral epicondylitis, also known as “tennis elbow.” Patients with RTS suffer tenderness at the lateral epicondyle and along the course of the PIN. Provocative tests for RTS include resisted forearm supination and the middle finger test. The latter is a maneuver in which the patient extends the elbow and holds the middle finger in extension against a force applied to the dorsal aspect of the proximal phalanx. This action can cause pain in the forearm. Both tests can be positive in lateral epicondylitis, however. Selective injections into the lateral epicondylitis, however. Selective injections into the lateral epicondyle or radial tunnel can help to differentiate between RTS and lateral epicondylitis.

Imaging Studies. Preoperative imaging includes plain x-ray films of the involved area to rule out fracture, dislocation, or the presence of a foreign body. Plain x-ray films of the elbow are used to rule out complicated orthopedic injuries or disorders of the radial head. Magnetic resonance imaging is the definitive diagnostic test if a tumor is suspected on physical examination.

Electrophysiological Testing. The electrophysiological examination of the forearm supinator muscle is critical to the localization of the level of involvement in a patient with possible PIN injury. It can also help to rule out cervical radiculopathy as the cause of the described symptoms and signs. If paralysis persists, this testing should be performed 3 weeks after injury. By 12 weeks postinjury, motor unit potentials will be present and will help to differentiate between recoverable injuries and those requiring surgery. The classic electrophysiological examination of the radial nerve consists of a motor conduction study from the axilla to the bicipital external groove, orthodromic sensory conduction of the superficial branch from the thumb to the wrist, or onset latency and needle examination of the triceps, brachioradialis and ECU muscles. Posterior interosseous nerve conduction is determined according to the brachioradialis and ECU latency difference and usually shows a marked slowing and low amplitude across the lesion.

Seror has presented a new electrophysiological method of evaluating the PIN. In his technique, percutaneous stimulation is performed in the axilla and recording is performed in the brachioradialis and ECU muscles of both upper limbs. After obtaining five responses for each muscle, the shortest latency of the best-defined compound motor action potential is used to calculate the latency difference. For the electrode technique, stimulation is applied near the nerve: the electrode is inserted 5 to 6 cm above the epicondyle on the lateral aspect of the arm and the reference electrode is located 20 mm proximally. Recording is performed using surface electrodes fixed onto the belly of the brachioradialis muscle 3 cm distal to the elbow, and on the belly of the ECU muscle at the midforearm close to the ulnar crease. The reference electrode is fixed to the thumb.

Milcan, et al. investigated electrophysiological testing in PIN syndrome. After using this test, these authors found that among 33 patients thought to have lateral epicondylitis, a diagnosis of PIN syndrome was made in 22 (66.7%).

Sarris, et al. do not advocate electrodiagnostic studies in the diagnosis of RTS. Note that, in general, reliable motor nerve conduction velocity data are rarely obtained in either syndrome because of technical factors relating to the tolerance of a painful proximal stimulus and needle motion with stimulation.

Surgical Approaches. The forearm was placed in supination and an 8- to 10-cm incision was made along the brachioradialis muscle from the distal arm into the forearm (Fig. 4 upper). The brachial fascia was exposed using blunt and sharp dissection and then incised. The brachioradialis muscle was mobilized laterally to expose the radial nerve (Fig. 4 center and lower), which at this point lies anterior to the lateral epicondyle of the humerus. Using a Penrose drain, the radial nerve was very gently moved slightly anteriorly to reveal first its branches to the brachioradialis and ECRL muscles and then its division into the SSRN and PIN (Fig. 5). Variations in this branching have been described earlier in this paper. This point of bifurcation varied, but was generally an approximate 1 to 1.5 inches distal to the antecubital flexion crease. Vessels from the recurrent radial artery that cross the PIN distal to the branching point were dissected away from the nerve and cauterized. The SSRN could then be dissected back to the main radial nerve trunk. Note that this step is important to ensure that subsequent regeneration through a more proximal repair of the main radial nerve is directed solely into the PIN. The PIN is then followed distally beneath the superficial head of the supinator muscle, which is divided longitudinally to expose the entire course of the PIN. All branches to the extensor musculature were carefully preserved.

Intraoperative NAP testing was performed after exposing the PIN. If an in continuity lesion was present and an NAP could be transmitted through the lesion, neurolysis was performed. If the NAP was absent, the lesion was resected and a repair made, including either an end-to-end suture anastomosis or a graft repair. The local SSRN was usually harvested for the graft repair: the fascicles present in the proximal SSRN stump were coagulated using fine-tipped bipolar forceps, and this stump was buried deep to the brachioradialis muscle.

Some authors prefer a posterolateral approach first for the forearm radial nerve, and then the PIN. A five-step approach has been described for such an exposure. 1) A preoperative palpation of the interval between the ECRL and brachioradialis muscles is performed by having the patient extend the wrist against resistance. 2) A longitudinal incision beginning just distal to the skin flexion crease at the elbow level is made along the preoperatively palpated line. This line follows the course of the SSRN. The posterior cu-
The posterior interosseous nerve (PIN) lies between the extensor carpi radialis longus (ECRL) and brachioradialis muscles and aids in defining the interval. 3) After opening the muscle fascia, passive extension and flexion of the wrist permits identification of the demarcation between the ECRL and brachioradialis muscles; the radial nerve appears at the bottom of the exposure. Dissection is extended in a distal to proximal direction along this nerve’s dorsal surface until the motor branch to the ECRB muscle, the SSRN, and the PIN are encountered. Immediately distal to the elbow, the radial nerve is consistently crossed transversely by several moderately sized vessels. These are divided to provide access to the radial nerve and are seldom

Fig. 4. Drawings depicting the anatomy surrounding the PIN. **Upper:** An incision (dotted line) begins on the distal lateral upper arm between the proximal brachioradialis and biceps muscles and extends to the lateral portion of the flexor crease of the elbow. It then follows the medial edge of the brachioradialis muscle into the forearm. **Center:** Retraction of the brachioradialis muscle after mobilization is necessary to expose the radial nerve and its branches, which lie underneath this muscle. **Lower:** Once the brachioradialis muscle is retracted, as shown here, the radial nerve is visualized. The superficial sensory radial nerve leaves the radial nerve as the PIN takes off. The volar supinator muscle, under which lies the PIN, has been released and is done so in cases of PIN entrapment by the supinator muscle. M. = muscle.
the site of nerve compression. 4) The ECRB fascial edge is released. 5) The fibrous proximal margin of the supinator muscle—that is, the arcade of Frohse—is identified and released. The radial nerve and its branches can now be seen. With each approach described, other potential areas of compression should be released, which in addition to the vascular leash of Henry include the fascia around the radio-capitellar joint. The radial nerve is now lifted and rolled laterally to expose the PIN branch arising from its deep surface. Dissection is then performed in a proximal to distal fashion along the PIN. Closed Metzenbaum scissors are then passed distally down both the SSRN and PIN branches to confirm that no residual constrictions are present. The Metzenbaum scissors are also passed proximally along the main trunk of the radial nerve to a distance 2 cm proximal to the elbow.

**Patient Population**

Forty-three patients with 45 PIN injuries or entrapments underwent surgery between 1967 and 2004 at LSUHSC or SUMC (two patients had bilateral lesions). The patients’ charts were reviewed retrospectively. The LSUHSC grading system was used to evaluate PIN functional loss and recovery (Table 1). All patients experienced a loss of function in the ECU, extensor digitorum, extensor indicis, extensor digiti minimi, EPB, EPL, and APL muscles.

**Results**

Twenty-five nontraumatic mechanisms of injury to the PIN included 21 entrapments and four tumors (Table 2). Tumors involving the PIN had either a neural origin (a schwannoma and a neurofibroma) or a nonneural origin (a ganglion cyst and a lipoma). Traumatic mechanisms of injury included nine lacerations, eight fractures, and three contusions.

Presentations consisted of weakness in the 1) ECU muscle together with compromised wrist extension and a radial drift; 2) extensor digitorum, indicis, and digiti minimi muscles, causing paretic finger extension; 3) EPB and EPL muscles, resulting in weak thumb extension; and 4) APL with rare decreased thumb abduction for reasons described in our introductory remarks (Fig. 6).

On surgery, in continuity lesions were found in 21 cases of PIN lesions associated with entrapment and in three cases of contusion-related injuries. These in continuity lesions transmitted NAPs and were treated using neurolysis (Table 3).

There were nine lacerating injuries involving the PIN. Three of these nine PINs appeared to be in continuity at the time of surgery, although intraoperative NAPs were absent. Thus, two nerves were treated with secondary end-to-end suture anastamosis and one nerve with a secondary graft repair (Table 4). There were six transected nerves; three were repaired with a primary end-to-end suture, two with a secondary end-to-end suture, and one with a graft.

Three fracture-related lesions occurred in continuity and were treated using neurolysis. There were four additional fracture-related injuries that occurred in continuity but required graft repair. Furthermore, one PIN transection associated with a fracture required graft repair. Four tumors involving the PIN were resected.

The duration of time between the injury and the actual surgery varied depending on the nerve injury. Tumors were surgically treated without delay. A sharp laceration injury, if not in continuity, was repaired within 72 hours postinjury if

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**TABLE 1**

Grading of PIN function*

<table>
<thead>
<tr>
<th>Grade</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>no ECU, ED, or EPL muscle function</td>
</tr>
<tr>
<td>1</td>
<td>trace function or contraction against gravity only for ECU muscle</td>
</tr>
<tr>
<td>2</td>
<td>recovery of ECU muscle function; absent or trace function in ED &amp;/or EPL muscle</td>
</tr>
<tr>
<td>3</td>
<td>recovery of ECU muscle function; some ED muscle function; weak or absent EPL muscle function</td>
</tr>
<tr>
<td>4</td>
<td>recovery of moderate strength in ED &amp; EPL muscles; full strength in ECU muscle</td>
</tr>
<tr>
<td>5</td>
<td>recovery of full strength in EPL, ED, &amp; ECU muscles</td>
</tr>
</tbody>
</table>

* ED = extensor digitorum.

**TABLE 2**

Outcomes in 45 surgically treated PIN lesions

<table>
<thead>
<tr>
<th>Mechanism of Injury</th>
<th>No. of Surgically Treated Cases</th>
<th>No. w/ Outcome Grade ≥ 3</th>
</tr>
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<tbody>
<tr>
<td>compression</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>laceration</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>fracture</td>
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<tr>
<td>tumor</td>
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<td>4</td>
</tr>
<tr>
<td>contusion</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>total</td>
<td>45</td>
<td>43</td>
</tr>
</tbody>
</table>

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Posterior interosseous nerve entrapments or injuries

The causes of PIN entrapments and injuries are legion. The PIN is the most frequently injured nerve in Monteggia fracture-dislocations, 45 which consists of four types. Monteggia fracture-dislocation Types I, II, and III are associated with anterior, posterior, and lateral dislocations of the radial head, respectively. These three fracture-dislocations are in turn associated with a short oblique or greenstick fracture of the diaphysis or proximal metaphysis in Types I and II and with a metaphysis fracture in Type III. Type IV includes features of Type I combined with an additional radius shaft fracture distal to an ulnar fracture. Posterior interosseous nerve injuries are most often associated with Type III Monteggia fractures. 55 An un reduced radial head in a Monteggia fracture resulting in a PIN palsy was described in a case report and later cited as a cause of PIN palsy in more recently published literature. 17

Although the PIN is the most frequently injured nerve in a Monteggia fracture, the overall incidence of PIN injury in this context is actually low. In the recent literature, Monteggia fractures in case reports and series reviewed by Ristic, et al., 41 were associated with few or no PIN injuries. Most PIN injuries reviewed by those authors resolved without intraoperative intervention, that is, after closed reduction.

There can be a delayed presentation of a PIN palsy following radial head dislocation, as long as 39 years according to a case report by Hashizume and colleagues. 21 In that case, at surgery, the PIN was compressed and narrowed at the arcade of Frohse. Resection of the radial head and release of the arcade was performed; the paralysis began to resolve immediately after surgery and continued to disappear by 6 weeks postoperatively.

The PIN is vulnerable to injury during operations not only on the radial head, but also on its neck. 22 Injury to the PIN may also occur due to direct pressure on or traction from the radial head, or entrapment between the radial head and the ulna. In the proximal forearm, the PIN is at risk during radial nerve graft placement. The patient’s function improved from an inability to extend the thumb and fingers to full function of all involved muscles.

Another prevalent mechanism of PIN injury is an accident causing an open wound in the forearm. However, PIN injuries associated with missile injuries have rarely been reported in the recent literature. Taha and Taha 43 reported on 41 patients who had sustained surgically treatable missile injuries to the radial, median, and/or ulnar nerves between the wrist and axilla. There was only one PIN injury (2.4%) in this group and treatment resulted in a good recovery.

There has been a case report on a complete division of the PIN following elbow arthroscopy. 16 This injury resulted in a neuroma, which was treated with resection followed by sural nerve graft placement. The patient’s function improved from an inability to extend the thumb and fingers to full function of all involved muscles.

Another prevalent mechanism of PIN injury is an accident causing an open wound in the forearm. However, PIN injuries associated with missile injuries have rarely been reported in the recent literature. Taha and Taha 43 reported on 41 patients who had sustained surgically treatable missile injuries to the radial, median, and/or ulnar nerves between the wrist and axilla. There was only one PIN injury (2.4%) in this group and treatment resulted in a good recovery.

Tumors tend to be associated with the PIN. 61 A case of PIN involvement by an intraneural ganglion was reported by Hashizume, et al. 19 Posterior interosseous nerve palsy is indirectly associated with these PIN-associated ganglia have also been reported. 20 After operations on the dorsum of the
wrist, usually for ganglia, distal PIN neuromas developed in six patients in this study; these lesions were resected. Proximal radius parosteal lipomas resulting in PIN palsies were reported on by Hanlon, et al.,\textsuperscript{18} and Nishida, et al.\textsuperscript{56} Such lipomas are related to but do not cause a change in the periosteum, in contradistinction to the periosteal lipoma, which originates in the periosteum.\textsuperscript{56}

In addition to the extraarticular soft tissue tumors, enlargement of the bicipital bursae can cause PIN palsies.\textsuperscript{51} There have also been a few reports over the last 10 years of PIN palsies caused by intraarticular elbow lesions as well as by elbow joint synovial chondromatosis,\textsuperscript{61} intracapsular chondroma,\textsuperscript{51} synovial hemangioma,\textsuperscript{6} and pseudogout.\textsuperscript{54} There have also been two case reports on patients with rheumatoid arthritis resulting in a PIN palsy, each of whom presented with finger drop.\textsuperscript{53,56} The PIN injuries were due to hypertrophied and inflamed elbow joint capsules causing PIN compression against the fibrous arcade of Frohse.

There has been one case report of an acute PIN palsy caused by septic arthritis of the elbow.\textsuperscript{26} The nerve was compressed beneath the arcade of Frohse by hypertrophied synovium and joint fluid at the anterior aspect of the radial neck. The nerve recovered after decompression, synovectomy, and irrigation of the elbow joint.

Posterior interosseous nerve palsy has resulted from hypertrophied venous components after brachiocephalic arterial venous fistulas construction for chronic hemodialysis in two patients with end-stage renal disease.\textsuperscript{59} There was also a report of a PIN palsy after intravenous cannulation of the forearm.\textsuperscript{59}

Sporadic single case reports included one by Wilson, et al.,\textsuperscript{58} who described an upholsterer with a PIN palsy, and one by Giese and Hentz,\textsuperscript{55} who detailed a nonsurgical PIN syndrome due to deep tissue massage. There has also been a report of bilateral PIN entrapment in a weight lifter.\textsuperscript{46} Dickerman, et al.,\textsuperscript{11} have described a case of RTS in an athlete who presented with a compressive sensory neuropathy.

**Differential Diagnoses**

A PIN palsy must be distinguished from a seventh cervical root syndrome, because the two can present in a similar fashion. In C-7 nerve root involvement, unlike in the PIN palsy, the triceps muscle is involved. Also, in C-7 nerve root injury, the wrist extensor muscles are usually spared, whereas as a PIN palsy results in weakness of the wrist extensor muscle together with radial drift.

A more proximal radial nerve injury must also be differentiated from a PIN palsy. A radial nerve injury typically produces a complete wrist drop because the ECRL muscle is innervated by the radial nerve before the origin of the PIN.\textsuperscript{58}

**Anatomical Considerations in Avoiding PIN Injury**

Diliberti, et al.,\textsuperscript{12} studied 32 fresh cadaveric upper extremities and exposed the proximal radius and elbow joint via a posterolateral approach. This approach is also useful in excision of the radial head, reduction and internal fixation of the radial head and neck as well as some distal humerus fractures, repair of a ruptured biceps tendon as part of a two-incision technique, and resection of a proximal radioulnar synostosis. The PIN is at risk during this exposure as it crosses obliquely through the surgical field from a proximal anterior to a distal posterior location. If the forearm is pronated, the PIN lies in a more anteromedial position and thus is subject to less risk of injury. Diliberti, et al., found that the safety zone between the PIN and the exposure, proximally, was a mean 52 \( \pm \) 7.8 mm. Supination decreased the safety zone to a mean of 33.4 \( \pm \) 5.7 mm. The angle formed by the PIN and the radial shaft in supination was 47.4 \( \pm \) 6.8, which decreased to 27.8 \( \pm \) 6.7 with pronation. Thus, approaching the lateral aspect of the proximal radius is safest in pronation.

Witt and Kamineni\textsuperscript{20} dissected 21 cadaveric elbows and determined the PIN relationships to various structures on a

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**TABLE 4**

Operative findings and operations for nonentrapment PIN injuries*\textsuperscript{a}

<table>
<thead>
<tr>
<th>Injury</th>
<th>Operative Findings</th>
<th>NAP</th>
<th>Operation Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>laceration</td>
<td>transection</td>
<td>NA</td>
<td>primary suture</td>
</tr>
<tr>
<td>fracture</td>
<td>transection</td>
<td>NA</td>
<td>secondary suture</td>
</tr>
<tr>
<td>contusion</td>
<td>in continuity‡</td>
<td>+</td>
<td>neurolysis</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>–</td>
<td>neurolysis</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>–</td>
<td>secondary graft</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>–</td>
<td>secondary graft</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>–</td>
<td>secondary graft</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>+</td>
<td>neurolysis</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>+</td>
<td>neurolysis</td>
</tr>
<tr>
<td></td>
<td>in continuity</td>
<td>–</td>
<td>secondary graft</td>
</tr>
</tbody>
</table>

\textsuperscript{a} NA = not applicable due to transection; – = absent; + = present.

\textsuperscript{‡} Prior primary suture.

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Fig. 7. Photograph obtained 2 years postneurolysis of an entrapped PIN. The preoperative wrist extensor muscle weakness combined with radial drift and the loss of finger and thumb extension and thumb abduction has been totally regained.
Posterior interosseous nerve entrapments or injuries

They found that at the distal end of the exposure, the first branches at risk, that is, the ECU muscle branches, had a mean 6 ± 1 cm distance from the articular surface of the radial head. They also pointed out that when using the posterolateral approach, the interval between the ECU muscle and the anconeus muscle must be clearly identified with the forearm fully pronated. The supinator muscle should be released close to its ulnar border. These authors found that it was safe to expose the proximal radius as far as the distal aspect of the bicipital tuberosity.

Imaging Studies

During the last decade, ultrasonography has gradually become an important tool with which to diagnose the supinator syndrome. High-resolution ultrasonograms can depict the PIN as it pierces the supinator muscle: well-delineated hypoechoic nerve fascicles are visibly embedded in the hyperechoic connective plane intervening between the superficial and deep portions of the supinator muscle.

In one case report, Chien, et al., revealed PIN compression as the cause of right forearm atrophy in a patient by using ultrasonography studies. The patient had normal brachioradialis, wrist flexors and extensors, and digital flexor muscles; however, no digital metacarpophalangeal or thumb joint extension was present. The sensory examination findings were normal. Electromyography studies documented a severe right PIN neuropathy. Magnetic resonance imaging results showed a mass along the course of the PIN proximal to its passage between the superficial and deep heads of the supinator muscle. The mass was isointense to the PIN on T₁- and T₂-weighted images. Ultrasonography studies confirmed the mass as described, but also depicted a transverse band distal to the mass, which crossed anteriorly to the nerve. The nerve was thickened proximal to the mass. On surgical exploration the supinator muscle was found to be divided at its proximal extent, and the fibrous band seen on ultrasonography was confirmed to be compressing the nerve. Focal swelling of the nerve just proximal to the fibrous band, which was released, was also corroborated and the nerve was thickened proximal to the focal swelling. Chien, et al., believe that ultrasonography should be used to diagnose this syndrome, because the former has high spatial resolution, no ionizing radiation, good control of the imaging plane of orientation, and easy applicability together with wide availability.

Four cases in which ultrasonography was used to diagnose supinator syndrome subsequently treated using surgical decompression were described by Bodner, et al., they assessed the PIN’s shape and echo texture on ultrasonography. When PIN swelling was suspected, they used longitudinal scanning to show the caliper change of the affected nerve and performed color Doppler ultrasonography to assess vascularization of the nerve and surrounding tissue. Ultrasonography examinations were also performed by these authors in 10 asymptomatic volunteers to establish mean anteroposterior (1.31 mm) and transverse (2.14 mm) diameters of the PIN. Given that supinator syndrome does not always demonstrate electrophysiological abnormalities, ultrasonography studies may serve as an adjunct with which to confirm such cases. Their analysis represents the first in which noninvasive diagnostic imaging was used to visualize normal as well as abnormal PIN conditions.

Physiological Mechanisms of PIN Injury

Intraneural swelling can occur 8 hours after nerve constriction according to findings in animal studies. This edema normalizes 1 month after the cause of the constriction is resolved. The edema is thought by most to be caused in part by an obstruction of the normal cytoplasmic axonal transport, that is, axonal damming. Cadaveric study data have also confirmed nerve swelling proximal to a compression. In these cadaveric studies the enlarged nerve was also associated with perineural or epineural fibrosis.

Treatment Options

Posterior interosseous nerve injuries are characterized as open or closed injuries. Open injuries include those due to penetrating wounds, lacerations, or surgical explorations in proximity to the PIN and these require exploration. Closed injuries, that is, those associated with orthopedic trauma other than fractures, compression, or neuritis, can usually be monitored. Conservative treatment consists of a wrist splint and hand therapy to prevent joint stiffness or permanent functional loss. Fractures resulting in a closed PIN injury are observed for a period of 3 months before surgical exploration. Idiopathic causes of PIN paralysis can be treated conservatively after treatable causes such as tumors have been excluded. However, if significant paresis or paralysis persists, then exploration, neurolysis, and NAP recordings are warranted.

Although the PIN is not often divided in lacerations given the nerve’s deep position, surgical exploration of the nerve should be performed because acute repair of a sharp transsection does well. The surgical options for open PIN injuries in continuity include neurolysis alone if there is an NAP transmission and resection with end-to-end or graft repair if there is no NAP. Nerve transfer has also been reported as an alternative to tendon transfer after complete functional loss in the PIN or a significant delay in treatment.

Conclusions

Although PIN palsies are not common, 45 PIN entrapments or injuries were surgically managed at LSUHSC or SUMC. Patients who underwent surgical repair for entrapments or injuries responded well to PIN release and/or repair, and thus surgical treatment of PIN palsies is an effective approach.

References


D. H. Kim, et al.
Posterior interosseous nerve entrapments or injuries


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