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Localizing the Posterior Interosseous Nerve with Anatomic Landmarks During Surgical Approaches of the Lateral Elbow

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Abstract

The Posterior Interosseous Nerve (PIN) represents a critical neurovascular structure within the surgical field of the lateral approaches to the elbow. The PIN innervates the extensor muscles of the forearm, while also sending sensory fibers to the dorsal wrist capsule, and iatrogenic injury during surgical exposure can compromise these functions. Thus, a thorough understanding of how to localize the PIN with anatomic landmarks is needed to best avoid this complication. The literature describes utilizing the radiocapitellar joint, radial tuberosity, lateral epicondyle, and the transepicondylar distance to localize the PIN. Moreover, pronation relocates the PIN to more distal position due to tethering within the supinator muscle, and this protects the nerve regarding surgical work in the lateral elbow vicinity, such as on the radial head and neck. In this review, we report the literature describing the strategies to localize the PIN from anatomic landmarks with respect to surgical approaches of the lateral elbow.

Keywords: Posterior interosseous nerve; Location; Anatomic landmarks; Lateral elbow approaches

Abbreviations: PIN: Posterior Interosseous Nerve; ECRL: Extensor Carpi Radialis Longus; ECRB: Extensor Carpi Radialis Brevis; EDC: Extensor Digitorum Communis; ECU: Extensor Carpi Ulnaris; EDM: Extensor Digitorum Minimus; APL: Abductor Pollicis Longus; EFB: Extensor Pollicis Brevis; EPL: Extensor Pollicis Longus; EIP: Extensor Indicis Proprious; TED: Transepicondylar Distance

Introduction

The Posterior Interosseous Nerve (PIN) innervates the extensor muscles of the forearm, while also providing sensory fibers to the dorsal wrist capsule. The PIN arises from the radial nerve proper, which in turn arises from the posterior cord of the brachial plexus receiving contributions from the fifth through eighth cervical roots. At the level of the radiocapitellar joint, the radial nerve proper bifurcates into the PIN and the superficial radial nerve. The PIN then courses laterally and posteriorly beneath the proximal edge of the supinator muscle, also known as the arcade of Froshe, before branching to give off its muscular innervations traveling posterior to the interosseous membrane. While there is variability, classic teaching claims the PIN innervates the extensor muscles in the order of the brachioradialis, Extensor Carpi Radialis Longus (ECRL), Extensor Carpi Radialis Brevis (ECRB), supinator, Extensor Digitorum Communis (EDC), Extensor Carpi Ulnaris (ECU), Extensor Digitorum Minimus (EDM), Abductor Pollicis Longus (APL), Extensor Pollicis Brevis (EPB), Extensor Pollicis Longus (EPL), and Extensor Indicis Proprious (EIP) [1].

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The PIN represents a neurovascular structure at risk during the surgical approach to the radial head and neck in the management of fractures, arthritis, and contractures [2]. The commonly utilized approaches to the radial head and neck include the Kocher, EDC split, and Kaplan approaches. The Kocher approach utilizes the interval between the anconeus and the ECU, the EDC split approach longitudinally incises the EDC tendon, and the Kaplan approach employs the interval between the EDC and ECRB [3,4].

Risk of iatrogenic injury to the PIN with these lateral elbow approaches can be avoided or at least minimized with a detailed understanding of the PIN's anatomic course at the level of the radial head and neck. During these approaches, the PIN courses obliquely in the surgical field from a proximal-anterior position to a distal-posterior position [2]. It is noted that pronating the forearm relocates the PIN to a more anteromedial position, which better protects the PIN from iatrogenic injury during the surgery [2,5]. Moreover, various anatomic landmarks of the elbow can be utilized to locate the PIN [2,6-8]. This review will discuss the PIN's anatomic course with respect to the lateral approaches of the elbow and how to locate it using well-defined anatomic landmarks to minimize the risk of iatrogenic PIN injury.

The Location of the PIN from Anatomic Landmarks

The radiocapitellar joint, radial tuberosity, lateral epicondyle, and transepicondylar distance represent anatomical landmarks and methods to locate the PIN during a surgical approach to the lateral elbow. The average distance of the PIN from these respective anatomical landmarks are demonstrated in Table 1 and their respective studies are discussed below.

Distance from the Radiocapitellar Joint

Diliberti et al. [2] performed the Kocher approach on 32 fresh-frozen cadaveric specimens. In each specimen, the authors measured the distance from the most distal aspect of the capitellum surface to the point where the PIN crossed the midpoint of the proximal radial shaft. The length of the entire forearm was also measured by the distance from the capitellum surface to the radial styloid. With the forearm in maximum supination, the PIN measured 33.4 ± 5.7mm (range, 22—47mm) from the capitellum on average, whereas with the forearm in maximum pronation, the PIN measured 52.0 ± 7.8mm (range, 38—68mm) from the capitellum on average. Of note, elbow flexion and extension did not influence these measurements. The radial length was 229.2 ± 14.7mm (range, 208—259mm) on average, which entailed that the PIN was not encountered in the 14.5 ± 2.0% (range, 10—19%) of the proximal radius in forearm supination and 22.7 ± 3.0% (range, 17—27%) in forearm pronation.

Lawton et al. [9] also conducted a Kocher approach on 24 unembalmed cadaveric upper extremities and measured the distance from an 18-gauge hypodermic needle placed in the radiocapitellar joint to the point where the PIN crossed the midpoint of the radial shaft. In supination, the mean distance was 46 ± 5.0mm (range, 40—58mm). In neutral rotation, the mean distance was 53 ± 6.0mm (range, 43—69mm). And in pronation, the mean distance was 57 7.0mm (range, 45—73mm). The authors concluded that the minimum distance from the PIN to the radiocapitellar joint in their study was 40mm and that one should limit dissection to within 40mm from the radiocapitellar joint to be in the "safe zone" and avoid potential iatrogenic PIN injury regardless of forearm rotation.

Hackl et al. [10] also performed a Kocher approach in 6 fresh-frozen cadaveric specimens. To perform their

Table 1: The average distance of the Posterior Interosseous Nerve (PIN) from the radiocapitellar joint, radial tuberosity, and lateral epicondyle, as well as utilizing the Transepicondylar Distance (TED) to predict the distance from the lateral epicondyle, with respect to supination, neutral rotation, and pronation.

	Study	Supination	Neutral	Pronation
Distance from Radiocapitellar Joint	Diliberti et al. [2] (n=32)	33.4 ± 5.7mm	N/A	52.0 ± 7.8mm
	Lawton et al. [9] (n=24)	46 ± 5.0mm	53 ± 6.0mm	57 ± 7.0mm
	Hackl et al. [10] (n=6)	41.1 ± 3.6mm	N/A	61.8 ± 2.9mm
	Calfee et al. [5] (n=20)	32 ± 8.0mm	42 ± 10.0mm	56 ± 12.0mm
	Gruenberger et al. [8] (n=45)	35.9 ± 5.7mm	42.1 ± 7.4mm	48.9 ± 8.4mm
Distance from Radial Tuberosity	Strauch et al. [6] (n=33)	23.0mm (didn't report forearm rotation values)		
	Hackl et al. [10] (n=6)	11.0 ± 2.8mm	N/A	29.2 ± 6.2mm
Distance from Lateral Epicondyle	Kamineni et al. [7] (n=63)	45.7mm	53.5mm	63.0mm
	Gruenberger et al. [8] (n=45)	53.3 ± 6.3mm	58.6 ± 7.7mm	68.4 ± 7.8mm
Utilizing the Transepicondylar Distance (TED)	Kamineni et al. [7] (n=63)	72% of TED	84% of TED	100% of TED
	Gruenberger et al. [8] (n=45)	N/A	N/A	TED within ±2.0mm (with Method B)

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measurements, the authors dissected to visualize the PIN and marked its course with a fine, radiopaque suture. Then a 3D X-ray scan of the elbow in 60° of flexion was performed using a Siemens ARCADIS Orbic 3D C-Arm image intensifier with the elbow in pronation, neutral rotation, and supination. Finally, a 3D reconstruction was made using the software AGFA IMPAX EE and various measurements from anatomic landmarks to locate the PIN could be performed. In the coronal view, the PIN crossed the midpoint of the radial shaft at a distance of 16.9 ± 5.0mm from the radial head articular surface in supination, and at a distance of 33.4 ± 5.9mm in pronation. In the sagittal view, which would best represent the surgical view one would have during a lateral elbow approach, the PIN crossed the midpoint of the radial shaft at a distance of 41.1 3.6mm from the radial head articular surface in supination, and at a distance of 61.8 ± 2.9mm in pronation.

Calfee et al. [5] utilized the interval between the EDC and ECRB in 20 fresh-frozen cadaveric specimens. The authors measured the distance from the radiocapitellar joint to the midpoint of where the PIN crossed the axis of the radial shaft. Like Diliberti et al. [2], the total length of the radius was measured from radial head to the radial styloid. In supination, the PIN crossed the radius at a distance of 32 ± 8mm (range, 17—45mm) from the radiocapitellar joint. In neutral rotation, the PIN crossed the radius at a distance of 42 ± 10mm (range, 25—62mm). And in pronation, the PIN crossed the radius at a distance of 56 ± 12mm (range, 31—74mm). In addition to reporting that pronation moved the PIN more distal from the radiocapitellar joint, Calfee et al. [5] also found that in 11/20 of their cadaveric specimens, the PIN crossed the radius at, or distal to, the PIN's exit from supinator muscle when the arm was in pronation. On the other hand, when in neutral rotation or supination, the PIN crossed the radius while within the supinator muscle in all specimens. Overall, the authors found that rotating the forearm from supination to pronation caused the PIN to cross the radius at a point 24 ± 8mm more distal and the magnitude of change positively correlated with overall radius length.

Gruenberger et al. [8] performed an EDC-split approach on 45 fresh-frozen cadaveric specimens and measured the distance from the radiocapitellar joint to the leading edge of the PIN where it crossed the midpoint of the radial shaft. In supination, the mean distance was 35.89 ± 5.70mm (range, 23.86—47.87mm). In neutral rotation, the mean distance was 42.06 ± 7.43mm (range, 25.79—57.05mm). And in pronation, the mean distance was 48.88 ± 8.38mm (range, 29.54—63.93mm). Overall, the authors found that taking the forearm from supination to pronation displaced the PIN a total of 12.99 ± 5.13mm (range, 4.64—29.98mm) more distal to the radiocapitellar joint.

Distance From the Radial Tuberosity

Strauch et al. [6] dissected 33 cadavers and measured the distance from the most prominent point of the radial tuberosity to the shortest distance to the PIN. The length of the entire radius was measured from Lister's tubercle to the radial head. In preserved cadavers, the authors found that the PIN was located 23mm (range, 18—32mm) from the radial tuberosity and that this distance was essentially unaffected by forearm rotation. In fresh-frozen cadavers, the radial tuberosity-to-PIN distance was 20mm (range, 18—23mm). Moreover, Strauch et al. [6] found no correlation between forearm length and radial tuberosity-to-PIN distance. The authors concluded that the PIN was found no closer than 18mm from the radial tuberosity and that pronation can help protect the PIN during lateral exposures of the elbow, although the radial tuberosity-to-PIN distance does not noticeably change.

From the same study mentioned previously, Hackl et al. [10] also utilized their 3D X-ray scan and 3D reconstruction method to measure the distance of the PIN from the most prominent aspect of the radial tuberosity in 6 fresh-frozen cadavers. In the coronal view, the PIN crossed the midpoint of the radial shaft at a distance of 9.6 ± 5.2mm distal from the radial tuberosity in supination, and at a distance of 4.9 ± 2.2mm in pronation. In the sagittal view, the PIN crossed the midpoint of the radial shaft at a distance of 11.0 ± 2.8mm distal to the radial tuberosity in supination, and at a distance of 29.2 ± 6.2mm in pronation.

Distance From the Lateral Epicondyle

Kamineni et al. [7] utilized a muscle splitting approach in 63 cadavers and measured the distance from the lateral epicondyle to the point where the PIN crossed the midpoint of the radius made by line between the lateral epicondyle and the radial styloid. With the forearm in supination, the distance was 45.7mm (range, 33.0—61.9mm). With the forearm in neutral rotation, the distance was 53.5mm (range, 34.3—70.6mm). And with the forearm in pronation, the distance was 63.0mm (range, 34.5—80.6mm).

In addition to measuring the PIN's distance from the radiocapitellar joint, Gruenberger et al. [8] also measured the distance from the lateral epicondyle to the leading edge of the PIN where it crossed the midpoint of the radial shaft through an EDC-split approach. In supination, the mean distance was 53.34 ± 6.25mm (range, 41.82—69.13). In neutral rotation, the mean distance was 58.55 ± 7.68mm (range, 43.83—74.74). And in pronation, the mean distance was 68.35 ± 7.80mm (range, 56.28—87.61). Overall, the authors found that taking the forearm from supination to pronation displaced the PIN a total of 15.01 ± 4.56mm (range, 9.05—26.87mm) more distal to the lateral epicondyle.

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Utilizing the Transepicondylar Distance

Both Kamineni et al. [7] and Gruenberger et al. [8] in their studies proposed utilizing the transepicondylar distance (TED) to predict the location of the PIN relative to the lateral epicondyle. Kamineni et al. [7] remarked how absolute measurements derived from previous cadaver studies do not always normalize for a particular individual due to variable body sizes. Moreover, bony landmarks can be limited by body habitus or injury affecting those landmarks, and further may require more undesirable dissection for accurate use. Thus, Kamineni et al. [7] argue for a non-invasive parameter using external landmarks to localize the PIN, in which they propose the transepicondylar distance (TED). The TED is the distance between the medial epicondyle and the lateral epicondyle that one can measure externally using a digital caliper or tape measure.

After measuring the PIN's distance from the lateral epicondyle in the study previously mentioned, Kamineni et al. [7] then compared this measurement with respect to the TED. The authors found the average TED was 63.59mm (range, 53.0—80.0mm). In supination, the average PIN distance from the lateral epicondyle was 72% (range, 71.7—72.6%) of the TED. In neutral rotation, the average PIN distance from the lateral epicondyle was 84% (range, 84.4—84.7%) of the TED. And in pronation, the average PIN distance from the lateral epicondyle was 100% (range, 98.7—101.4%) of the TED. From these results, the authors derived the colloquial and approximate "70-85-100 rule" that one can use to approximate the PIN's distance from the lateral epicondyle using the percentage of the TED throughout forearm rotation. Moreover, Kamineni et al. [7] utilized these results as predictive values and found in supination, the PIN was within 10mm of 70% of the TED in 73.01% of cases, within 15mm in 85.7% of cases, and within 20mm in 95.23% of cases. In neutral rotation, the PIN was within 10mm of 85% of the TED in 63.5% of cases, within 15mm in 84.12% of cases, and within 20mm in 93.7% of cases. And in pronation, the PIN was within 10mm of the TED in 50% of cases, within 15mm in 71.43% of cases, and within 20mm in 90.47% of cases.

Gruenberger et al. [8] also reported the TED in 45 fresh-frozen cadavers as their method to predicting the PIN's location from both the lateral epicondyle and the radiocapitellar joint throughout forearm rotation. The authors used two methods to measure the TED, which included using an electronic caliper, defined as Method A, and then using a sterile tape measure, defined as Method B. In Method A, the average TED was 63.2 ± 6.1mm (range, 52.5—76.0mm). The median difference between the TED in Method A and actual distance from the PIN to the lateral epicondyle in pronation was -5.6mm (range, -19.3 –7.6mm). The TED significantly correlated with the distance from the PIN to the lateral epicondyle in pronation ($r^2 = 0.266$, $p<0.001$), but did not significantly correlate in neutral rotation or supination. Furthermore, the TED did not correlate with the PIN's distance from the radiocapitellar joint in either pronation, neutral rotation, or supination. In Method B, the average TED was 68.4 ± 8.7mm. Again, there was a significant correlation between the distance from the PIN to the lateral epicondyle in pronation (r2 = 0.95, $p<0.001$). The average distance between the TED and actual distance from the PIN to the lateral epicondyle in pronation was ±2mm (range, -4.0—2.0mm), which was significantly more precise than Method A ($p = 0.007$). Overall, Gruenberger et al. [8] concluded the TED measured with a sterile tape measure could best predict the PIN's location from the lateral epicondyle in pronation within ±2mm when one uses the EDC split approach.

Conclusion

The PIN innervates the extensor muscles of the forearm in addition to providing sensory fibers to the dorsal wrist capsule. It courses through the surgical field of lateral elbow approaches, making it a neurovascular structure at risk of iatrogenic injury. Therefore, a surgeon should have a thorough understanding of the PIN's anatomical location to avoid iatrogenic injury. The radiocapitellar joint, radial tuberosity, lateral epicondyle, and transepicondylar distance can all be utilized as methods to locate the PIN during a surgical approach to the lateral elbow. Furthermore, pronation can relocate the PIN to a more distal position as to protect it during surgical work on the radial head and neck. Depending on the specific patient case and the available intact anatomy, a surgeon can pronate the forearm and utilize these anatomical landmarks to safely locate and avoid iatrogenic injury to the PIN.

Conflicts of Interest: None

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