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# Morphology of the Ulnar Nerve in the Forearm and Hand, Including Its Variations

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**Abstract:** ***Background**: The medial cord of the brachial plexus gives rise to the ulnar nerve, which includes fibres from the ventral ramus of C7 (C8, T1). It gives off several branches in the forearm and in the hand, including articular, muscular, palmar cutaneous, dorsal, superficial terminal, and deep terminal branches. **Materials and methods**: This research investigated a total of 50 embalmed human bodies (25 from the right side and 25 from the left side) representing both genders within the adult demographic of South India. These specimens were sourced from the Department of Anatomy at Bangalore Medical College and Research Institute in Bengaluru. Variations were noted in the ulnar nerve concerning its presence, the path it takes relative to the artery, the level at which branches originate, and its connections with the median nerve. **Results**: The ulnar nerve was identified in all 50 specimens of upper limbs, resulting in a 100% presence rate. In around 88% of the instances, the dorsal cutaneous branch of the ulnar nerve emerged 5 cm above the pisiform bone. It then travelled down the medial aspect of the wrist and hand's posterior side, branching into medial and lateral divisions in all cases (100%) below the pisiform bone. In 12% of the instances, this branch appeared just beneath the elbow joint. Furthermore, terminal branches of the ulnar nerve showed trifurcation in 6% of cases. The superficial terminal branch stemmed from the ulnar nerve trunk and innervated one and a half medial fingers in 94% of cases; however, in 6% of occurrences, it provided sensation to two and a half medial fingers. **Conclusion**: Understanding these variations, along with the normal patterns, is beneficial for interventional radiologists, orthopaedic surgeons, and neurologists. This knowledge can help prevent iatrogenic injuries to the ulnar nerve during radiological procedures, surgeries for fractures, or the administration of diagnostic therapies.*

**Keywords:** Ulnar nerve, Nerves in the forearm, Nerves in the hand, Entrapment neuropathy

## 1. Background

The ulnar nerve (C8, T1) enters the forearm between the two heads of the flexor carpi ulnaris, located on the posterior and oblique portions of the ulnar collateral ligament at the elbow. It travels down the medial side of the forearm, resting on top of the flexor digitorum profundus; its upper section is covered by flexor carpi ulnaris, while the lower part is positioned laterally and surrounded by skin and fascia. In the upper third of the forearm, there is a space between the ulnar artery and the surrounding forearm tissue, whereas in other regions, it is positioned closely adjacent to this artery. [1]

Approximately 5 cm above the wrist, a dorsal branch arises that extends distally towards the hand. This branch moves anterior to the flexor retinaculum and posteromedially in relation to the ulnar artery before bifurcating into superficial and deep terminal branches. The positioning relative to both the brachial artery and the median epicondyle facilitates an easy tracking of its course.

The ulnar nerve gives rise to several branches: articular, muscular, palmar cutaneous, dorsal, as well as superficial and deep terminal branches. The articular branches serving the elbow are small filaments that emerge from between the medial epicondyle and olecranon. Muscular branches located near the elbow provide innervation to both the flexor carpi ulnaris and half of the flexor digitorum profundus. The palmar cutaneous branch originates around the mid-forearm, following along with the ulnar artery as it penetrates through the deep fascia to reach the palm skin; it sometimes supplies the palmaris brevis. The dorsal branch appears about 5 cm above the wrist; it courses beneath the flexor carpi ulnaris before continuing distally and posteriorly, where it splits into dorsal digital nerves that supply sensation to both the little finger and adjacent areas. These digital nerves extend partially or completely to their respective phalangeal bases, receiving additional contributions from median nerve fibers for sensation on the lateral aspect of the ring finger. [2]

The superficial terminal branch innervates the palmaris brevis as well as the skin on the medial palm by dividing into proper digital nerves for both little and ring fingers. Meanwhile, deep terminal branches accompany the ulnar artery, providing innervation to interossei muscles and lumbricals while also contributing to forming the deep palmar arch. [3]

Injuries impacting this nerve typically manifest as ulnar neuropathy at or around wrist level, resulting in muscle weakness and functional impairments within both the forearm and hand regions. [4]

## 2. Material & Method

The ulnar nerve was examined in a study involving 50 embalmed human cadavers. The subjects, representing the adult population from South India, were sourced from the Department of Anatomy at Bangalore Medical College and Research Institute. This sample included 25 upper limbs from the right side and 25 from the left, encompassing both male and female specimens. Dissection of the upper limbs was

conducted following the protocols outlined in the Cunningham practical manual. The research involved tracing the ulnar nerve through various anatomical landmarks, including the cubital tunnel, along the medial aspect of the forearm, and at Guyon's canal. Additionally, all associated muscular branches, dorsal cutaneous branches, and terminal branches were identified.

The study focused on several parameters:

- Presence or absence of the ulnar nerve
- Anatomical course in relation to nearby structures such as arteries, the medial epicondyle of the humerus, and Guyon's canal
- Levels where branches originate
- Connections with the median nerve

## 3. Results

The ulnar nerve was identified in every case (100%). In all specimens, the nerve supplying the flexor carpi ulnaris originated as expected from the ulnar nerve trunk and entered the muscle just distal to the elbow joint. Furthermore, all specimens exhibited that the nerve innervating the medial portion of the flexor digitorum profundus also originated normally from the ulnar nerve trunk, positioned just below the elbow joint level. No variations were observed in the muscular branches of the ulnar nerve.

Communication between the ulnar and median nerves was observed in 40 specimens (80%), primarily located in the palm area and absent in the forearm. In all cases (100%), the dorsal cutaneous branch of the ulnar nerve directly stemmed from its trunk. This branch was noted to arise 5 cm proximal to the pisiform bone in 44 specimens (88%). It then travelled downwards along the medial aspect of both the wrist and hand, dividing into medial and lateral branches distal to the pisiform bone in every instance (100%). In 6 specimens (12%), this branch originated just below where the elbow joint is located.

The superficial terminal branch emerged from the ulnar nerve trunk at a point distal to the pisiform bone across all specimens (100%). It provided innervation to one and a half fingers in 47 cases (94%). In contrast, three specimens (6%) received supply for two and a half fingers through both ulnar and radial sides of various digits, including aspects of both little and ring fingers, as well as part of the middle finger.

The deep terminal branch also arose from the ulnar nerve trunk at a level distal to the pisiform bone across all specimens (100%) and travelled deep alongside the deep branch of the ulnar artery. Bifurcation of the ulnar nerve into superficial and terminal branches was observed in 47 specimens (94%), while trifurcation into superficial, deep, and muscular branches occurred in three specimens (6%).

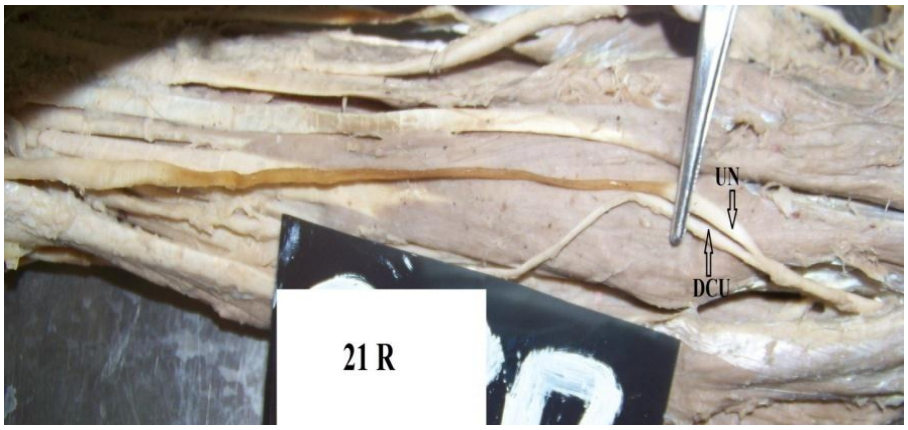


**Figure 1:** High division of the dorsal cutaneous nerve

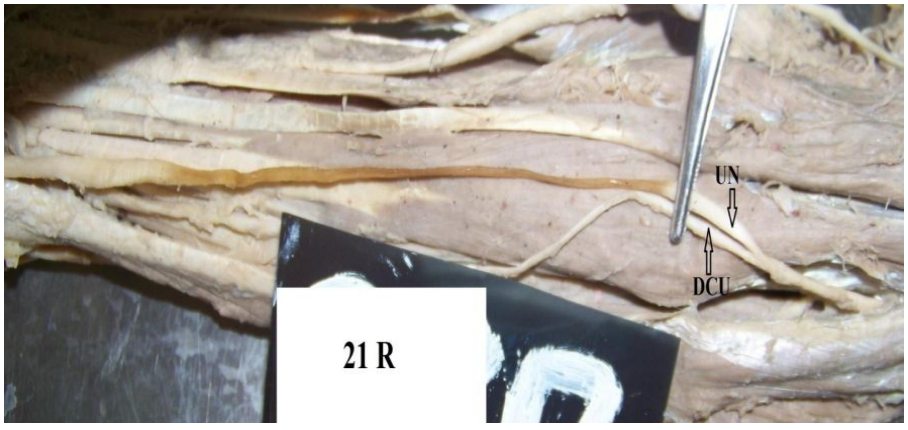


**Figure 2:** Medial two and a half digits


**Figure 3:** Trifurcation

## 4. Discussion

Variations in ulnar nerve branching patterns have been a subject of investigation among several researchers. Kaplan first identified a nerve branch from the dorsal cutaneous branch of the ulnar nerve, which merged with the superficial ramus of the ulnar nerve. Wulle also reported a case of a Kaplan anastomosis connecting to the ulnar nerve's superficial ramus. [5] Hoogbergen and Kauer found another instance of a Kaplan anastomosis originating from the dorsal cutaneous branch, situated approximately 2.5 cm proximal to the ulnar styloid process. This anastomosis yielded three branches, with the first one branching off just before reaching the ulnar styloid process, leading towards the radiocarpal joint. The anastomosis produced two additional branches directed at the abductor digiti minimi muscle and the fifth carpometacarpal joint, ultimately connecting with the deep ramus of the ulnar nerve. [6]

Georgis et al. described a slender nerve branch from the dorsal branch of the ulnar nerve, known as the Kaplan anastomosis, arising around 3 cm proximal to the ulnar styloid process. This branch ran parallel to the ulnar nerve and provided multiple fine branches to various structures, including synovial membranes, muscles, and skin, before merging with the trunk of the ulnar nerve. [7]

Paul et al. analysed the trajectory of the ulnar nerve in the forearm, observing its path between the heads of the flexor carpi ulnaris before giving rise to its dorsal branch. This dorsal branch, originating where the forearm is divided into four quarters, traverses downward alongside the flexor carpi ulnaris, turning at the wrist to situate itself between the flexor carpi ulnaris and ulna. It bifurcates into a medial branch, affecting the hypothenar eminence muscles, and a lateral sensory branch, innervating part of the dorsal hand and the medial digits, leaving the radial nerve to serve the lateral two and a half digits on the dorsal surface. [8]

Windisch highlighted that digital branches from the dorsal branch of the ulnar nerve innervated all areas of the little finger. [9] Ballesteros & Ramirez noted the presence of bilateral accessory abductor digiti minimi muscles encircling the ulnar nerve and artery, with sensory branches classified as either superficial or deep, originating from either the dorsal cutaneous branch of the ulnar nerve or the ulnar trunk. They identified a third sensory pathway leading towards the fourth finger, known as the "fourth common digital nerve." Their findings included an accessory head of abductor digiti minimi that emerged from both the flexor retinaculum and the palmaris longus tendon in the right hand, which obliquely passed through Guyon's canal, eventually combining into a single pennate muscle with the abductor digiti minimi. [10]

Lama et al. and Blair et al. reported a dorsal branch originating from the ulnar nerve trunk about a quarter of the way up from the lower end near the elbow. This branch is divided into three segments after descending along the flexor carpi ulnaris: a medial segment that branches to the hypothenar eminence and abductor digiti minimi muscle, and two lateral segments that become cutaneous nerves supplying sensation to the medial halves of the dorsum of the hand. [11]

Özdemir et al. specified that the dorsal cutaneous branch formed several centimetres above the humeral epicondylar line and progressed downwards, emphasising its precise intraneural pathway. [12] Sawant et al. elaborated that the dorsal branch, branching near the elbow, splits into three components, with the most medial one merging with fibers from the superficial palmar branch before serving the little finger. The lateral branches became cutaneous nerves supplying sensation to parts of the back of the hand. [13]

Gabriel's examination of 120 specimens revealed trifurcation within Guyon's canal on a few occasions, with noting accompanying the ulnar arteries. An accessory head for the abductor digiti minimi was observed in some hands, associated with trifurcation leading to superficial, deep, and muscular branches. [14] Further investigations by Ghabriel and Makar noted bilateral trifurcation in one cadaver, with one hand featuring an accessory head of the abductor digiti minimi. Several studies have proposed that space-occupying lesions within Guyon’s canal, such as lipomas or thrombosis linked to the ulnar artery or anomalous muscles, can compress the ulnar nerve. [15,16,17]

Additionally, Stopford's research presented abnormal cutaneous innervation patterns, where the ulnar nerve supplied both sides of the little and ring fingers, as well as part of the middle finger. In the current study involving three

specimens (6%), superficial branches from the ulnar nerve supplied sensation to two-and-a-half medial fingers.

Olave & Sol reported bifurcation taking place in the mid-tunnel regions of the hook-shaped hamate and discussed potential variations at this juncture, where atypical branches might emerge before the nerve enters the carpal tunnel. [18] Dodds et al.'s dissection of 58 hands found a 22.4% occurrence rate of anomalous muscle formations but only a 1.7% rate of atypical trifurcations concerning the ulnar nerves.

Three out of fifty specimens exhibited trifurcation, splitting into superficial, deep, and muscular branches. [19] Consistent with Bergman et al. and Bozkurt et al., a higher origin for medial proper digital nerves directed toward the little finger from the dorsal aspects related to the ulnar nerve was observed; six specimens (12%) mirrored this pattern, presenting a higher initiation point just below the elbow joint for their dorsal cutaneous branches. [20] The median-ulnar anastomosis, distinguished as the Martin-Gruber anastomosis, illustrates proximal connections where fibres from the median nerve converge distally with radial connections linked to the ulnar. Gruber's study of 250 forearms revealed 38 connections (15.2%), establishing the anastomosis's prevalence. It may manifest between deep flexor muscle branches, directly from the median to ulnar nerves or via anterior interosseous and ulnar combinations. [21, 22]

Mannerfelt and Kimura explored forearm ulnar-median connections affecting upper limb muscle innervation, influencing intrinsic hand muscle motor innervation. [23, 24] Meals and Shaner identified communication between these nerves in 40 of 50 dissected palms, paralleling multiple documented instances of sensory communication branches. [25] Another variant, ulnar-median anastomosis (Martin-Gruber reverse or Marinacci anastomosis), involves proximal ulnar branches connecting distally with the median nerve. Marinacci noted a patient with a median nerve injury in which hand muscle innervation persisted, citing this anastomosis as a rare anatomical anomaly. [26]

Further analysis by Almeida et al. suggested that Martin-Gruber or Marinacci anastomoses could arise from similar embryonic sources of both nerves, while Griot et al. reported over 90% exhibiting communication branches, prompting re-evaluation of these anatomical variations as normative. [27, 28] Uncommon branching variations of the ulnar nerve in the forearm may significantly influence clinical diagnoses, as seen in the extremely rare "all ulnar hand" variant, where both motor and sensory functionalities are exclusively ulnar-supplied without median or radial contributions.

Kazakos emphasised the potential diagnostic complexities of such anastomoses due to overlapping innervation from either nerve. [29] Consideration of anatomical positions during surgical interventions is imperative to avoid damaging these branches. Dogan's review indicated communication occurrences between the ulnar and median nerves, differentiating between the Martin-Gruber and Marinacci types, while the Riche-Cannieu and Berretini anastomoses involve interconnections among various branches in the palm areas. This study revealed that 80% of examined specimens showed communication between the ulnar and median nerves, primarily localised in the palms. [30]

## 5. Conclusion

Variations in the ulnar nerve are relatively common and can lead to conditions such as ulnar neuropathy, cubital tunnel syndrome, or entrapment within Guyon's canal. Diagnosis of these variations is often achieved through electrodiagnostic testing, with electromyography serving as an effective method for identifying atypical variations in the arm, forearm, and hand. The ulnar nerve ranks as the second most frequently affected nerve in cases of entrapment neuropathy. Understanding these variations is critical during surgical interventions at the elbow and wrist since unexpected anatomical differences may result in iatrogenic injury. Additionally, these variations can complicate the diagnosis of neurological syndromes. A comprehensive understanding of the ulnar nerve's distribution and its potential connections with the median nerve is essential in managing upper limb trauma. It is important to raise awareness regarding these variations and their prevalence.

Therefore, increasing knowledge about these variations relative to typical anatomical patterns is beneficial for interventional radiologists, orthopaedic surgeons, and neurologists. This awareness helps prevent inadvertent iatrogenic harm to the ulnar nerve during radiological procedures or surgical treatment of fractures and diagnostic therapies.

**Conflicts of Interest:** None

**Abbreviations:**
UN – Ulnar Nerve
DCU – Dorsal Cutaneous Branch of Ulnar Nerve

**Author Contributions**

Dr Vijay Kumar S: Concept, Design, Literature Search, Data Analysis, Statistical Analysis, Manuscript Preparation, Manuscript Editing, Manuscript

Dr Priya Ranganath: Manuscript Preparation, Manuscript Editing, Manuscript Review and final approval.
Dr Vikram S: Manuscript Preparation, Manuscript Editing, Manuscript Review.

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