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ORIGINAL ARTICLE

A Cadaveric Study of Anatomical Variations in the Course and Branching Pattern of the Median and Ulnar Nerves in the Palm

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ABSTRACT

Background: Anatomical variations in the course and branching pattern of the median and ulnar nerves in the palm hold significant clinical importance, particularly in the context of hand surgery, nerve repair, and regional anesthesia. Precise knowledge of these variations helps in minimizing iatrogenic injuries during surgical interventions.

Objective: To examine and document the anatomical variations in the pathway and branching pattern of the median and ulnar nerves in the palm through a cadaveric study.

Materials and Methods: This descriptive cadaveric study was conducted on 10 formalin-fixed adult human hands obtained from preserved cadavers in the anatomy department. Dissection was carefully performed in the palmar region to expose the median and ulnar nerves. Each hand was examined for the course of the nerves, number and pattern of branches, presence of communicating branches, and any unusual anatomical features.

Results: Anatomical variations were identified in 4 out of 10 dissected hands (40%). The median nerve displayed variation in the origin and number of common palmar digital nerves in 2 hands. Ulnar nerve variations included aberrant branching and communicating branches with the median nerve in 2 specimens. No significant asymmetry between left and right hands was observed.

Conclusion: The study demonstrated that anatomical variations in the median and ulnar nerves are relatively common even in a small sample size. These findings underscore the importance of preoperative anatomical awareness and careful dissection in surgical practice. Further large-scale studies are recommended to establish population-based anatomical baselines.

Keywords: Median nerve, ulnar nerve, Hand anatomy, Cadaveric study, palmar nerves, Anatomical variation, Nerve branching

INTRODUCTION

The human hand is an exceptionally complex and functionally versatile anatomical structure, enabling a wide range of fine motor tasks, from basic gripping to intricate manipulations involved in writing, tool use, and surgical precision[1]. This unique functionality is primarily attributed to the integrated action of musculoskeletal, vascular, and neural components, with the neuromuscular architecture playing a pivotal role in both motor control and sensory feedback. Among the most critical neurovascular structures governing the intrinsic and extrinsic functions of the hand are the median and ulnar nerves. These nerves are responsible not only for innervating the majority of the muscles of the forearm and hand but also for providing essential cutaneous sensory input to the palmar aspect of the hand, which is crucial for tactile discrimination and proprioception[2].

Accurate knowledge of the anatomical course, division, and branching pattern of these nerves is vital for medical professionals involved in diagnostic, interventional, and surgical procedures of the upper limb[3]. Whether performing open hand surgery, regional nerve blocks, microsurgical nerve repairs, or endoscopic interventions, the surgeon's understanding of anatomical variability directly impacts procedural safety, efficacy, and long-term functional outcomes. Textbook descriptions often depict a stereotypical configuration of these nerves; however, numerous studies have revealed substantial anatomical variations in their trajectory, branching hierarchy, and interconnections particularly in the palmar region[4].

The median nerve typically enters the palm via the carpal tunnel beneath the flexor retinaculum and divides into common palmar digital nerves, which further split into proper palmar digital branches supplying the thumb, index, middle, and lateral half of the ring finger[5]. In contrast, the ulnar nerve traverses Guyon's canal, located superficial to the flexor retinaculum, and bifurcates into superficial and deep branches, which innervate the hypothenar muscles, medial digits, and part of the palmar skin. Nonetheless, variations in their course such as early or high bifurcation, accessory digital branches, aberrant superficial branches, and the presence of neural communications like the Martin–Gruber or Riche–Cannieu anastomoses are well-documented and may pose significant intraoperative challenges. Moreover, coexistent vascular anomalies, such as a persistent median artery, can further complicate the surgical field and anesthetic spread[6].

These deviations from textbook norms are not merely academic curiosities but have profound implications in clinical contexts. Misidentification or unawareness of such variations may result in iatrogenic injuries, incomplete decompression during carpal tunnel release, or failure in achieving desired nerve blockade during regional anesthesia. This is particularly relevant in specialized surgeries such as tendon transfers, neurovascular reconstructions, or flap harvesting procedures where intricate anatomical details dictate success[7, 8].

Despite the global recognition of these variations, there is a marked paucity of region-specific data from South Asian populations, especially from Pakistan. Ethnic, genetic, and environmental factors may contribute to unique anatomical presentations in this demographic, necessitating localized anatomical studies. The limited availability of morphometric and morphological data in this population creates a critical gap in the knowledge base that may hinder surgical precision and elevate procedural risks[9, 10].

In response to this need, the present cadaveric study was undertaken with the aim of documenting the anatomical and morphometric variations in the course and branching pattern of the median and ulnar nerves in the palm in a sample of adult Pakistani cadavers. Through systematic dissection and detailed analysis, this research endeavors to enhance the anatomical database available to surgeons, anatomists, and clinicians. The ultimate goal was to support more accurate preoperative planning, reduce intraoperative complications, and contribute to the refinement of surgical and anesthetic techniques in hand-related procedures[11].

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MATERIALS AND METHODS

This descriptive, cross-sectional cadaveric study was carried out in the Department of Anatomy, Allama Iqbal Medical College, Lahore, Pakistan, over a six-month period from January 2023 to July 2023. The study aimed to assess the morphological and anatomical variations in the course and branching patterns of the median and ulnar nerves within the palmar region of adult human hands. The investigation was designed to enhance understanding of region-specific anatomical features relevant to clinical and surgical practices.

Sample Selection and Ethical Considerations: A total of 10 formalin-fixed adult human hands, obtained from five cadavers of both sexes, were included in the study. Only specimens free from external trauma, surgical scars, congenital malformations, or pathological changes were selected. The cadavers were sourced from the body donation program of the Department of Anatomy at Allama Iqbal Medical College. The study was conducted in compliance with institutional ethical standards and the principles outlined in the Declaration of Helsinki. Approval was granted by the Institutional Ethical Review Board prior to specimen dissection.

Dissection Protocol: Each hand was dissected using established anatomical methods. A midline incision was made along the palmar surface, followed by careful removal of subcutaneous tissue to expose the superficial palmar fascia. The palmar aponeurosis was retracted laterally to reveal the neurovascular contents of the palm. The median and ulnar nerves were then identified and meticulously traced from their points of entry at the wrist through the carpal tunnel and Guyon's canal, respectively to their terminal branches. Variations in nerve course, branching pattern, and any communicating branches (e.g., Martin–Gruber or Riche–Cannieu anastomoses) were carefully documented.

Data Documentation and Morphometric Measurements: Each specimen was assessed for the course of the nerves (straight, deviated, deep, or superficial), the number of branches originating from each nerve, the presence of communicating branches between the median and ulnar nerves, and any vascular anomalies such as a persistent median artery. Morphometric data were obtained using digital Vernier calipers (±0.01 mm precision), including nerve diameters and the distance of the first branch from anatomical landmarks like the distal wrist crease, pisiform bone, and hook of hamate. All findings were documented photographically using a high-resolution digital camera.

Data Analysis: Descriptive statistical analysis was conducted using Microsoft Excel. Frequencies and percentages were calculated for categorical variables (e.g., type of anatomical variation), while mean values and standard deviations (mean ± SD) were computed for continuous morphometric measurements. Due to the limited sample size, inferential statistical testing was not applied.

RESULTS

A total of 10 formalin-fixed adult human hands were dissected to assess anatomical variations in the course and branching patterns of the median and ulnar nerves in the palm. Anatomical variations were identified in 4 out of 10 specimens (40%). Variations involving the median nerve were found in 2 specimens (20%), while deviations in the ulnar nerve were also present in 2 specimens (20%). In one specimen (10%), a communicating branch between the median and ulnar nerves consistent with a Riche–Cannieu anastomosis was documented.

Among the median nerve variations, the most notable included early bifurcation into digital branches and the presence of an accessory common palmar digital branch. Ulnar nerve anomalies included an early superficial division and an aberrant superficial branch arising near the pisiform bone. These findings are of clinical relevance due to their potential implications in surgical planning and regional anesthesia.

Morphometric analysis revealed that the mean diameter of the median nerve was 2.6 ± 0.17 mm, while that of the ulnar nerve was 2.4 ± 0.13 mm. The mean distance from the distal wrist crease to the first nerve branch was calculated as 39.4 ± 2.0 mm. These values are summarized in Table 1 below.

Table 1: Morphological Variations and Morphometric Measurements of the Median and Ulnar Nerves in the Palm (n = 10)

Specimen No.	Median Nerve Variation	Ulnar Nerve Variation	Communication Observed	Median Nerve Diameter (mm)	Ulnar Nerve Diameter (mm)	Distance of First Branch from Wrist Crease (mm)
1	Normal	Normal	None	2.5	2.4	42
2	Early bifurcation into digital branches	Normal	None	2.8	2.5	38
3	Normal	Aberrant superficial branch near pisiform	None	2.6	2.2	41
4	High division with accessory digital branch	Normal	Present (Riche–Cannieu)	2.9	2.3	36
5	Normal	Early division into superficial and deep branches	None	2.7	2.6	40
6–10	Normal in all parameters	Normal in all parameters	None	Mean: 2.6 ± 0.17	Mean: 2.4 ± 0.13	Mean: 39.4 ± 2.0

Overall, median nerve anomalies (20%) included early bifurcation and high division with accessory digital branching, while ulnar nerve anomalies (20%) involved early superficial branching and aberrant divisions. The Riche–Cannieu anastomosis identified in 10% of specimens is clinically significant due to its role in modifying sensory and motor innervation patterns in the hand, potentially affecting both surgical outcomes and nerve conduction studies.

Although the sample size is limited, these findings highlight the considerable variability in palmar neuroanatomy and emphasize the importance of detailed anatomical assessment during preoperative planning and intraoperative dissection in hand surgeries.

DISCUSSION

The present cadaveric investigation highlights a substantial incidence of anatomical variations in the course and branching patterns of the median and ulnar nerves within the palmar region, with deviations observed in 40% of the dissected specimens[12]. These findings reaffirm the inherent complexity and interindividual variability of peripheral nerve anatomy in the human hand an anatomical challenge that continues to confront surgeons, anatomists, and clinicians involved in upper limb procedures[13].

In particular, the median nerve demonstrated notable variations, including early bifurcation and anomalous formation of common palmar digital nerves, which align with existing literature. Prior studies have reported early median nerve branching in approximately 25–30% of hands, emphasizing the relevance of such deviations during procedures like carpal tunnel release, nerve decompression, and tendon transfers[14]. Failure to recognize these atypical branching patterns may result in incomplete decompression, iatrogenic nerve injury, or persistent postoperative symptoms, underscoring the need for precise anatomical knowledge and intraoperative vigilance[15].

Similarly, ulnar nerve variations such as early superficial division and aberrant branching near the pisiform bone pose

significant risks during surgeries involving Guyon's canal. These deviations may alter expected anatomical landmarks and increase the complexity of procedures like ulnar tunnel release and hypothenar flap elevation[16]. Of particular clinical interest is the documentation of a Riche–Cannieu anastomosis in one specimen (10%), representing a communicating branch between the median and ulnar nerves. Such anastomoses may obscure the clinical presentation of nerve injuries and complicate diagnosis by producing atypical patterns of motor or sensory preservation. Moreover, these communications have been associated with false-negative results in electrophysiological studies, leading to potential misinterpretation in nerve conduction testing[17].

The morphometric findings specifically, the mean diameters of the median (2.6 mm) and ulnar (2.4 mm) nerves, and the average branching distance of 39.4 mm from the distal wrist crease are consistent with previously published anatomical data. These values serve as important reference points for microsurgical nerve repair, nerve grafting, and the accurate delivery of regional anesthesia in the palmar region. Such measurements can guide neurorrhaphy and nerve conduit selection by providing practical dimensions during intraoperative procedures[18, 19].

While the limited sample size (n = 10 hands) restricts the generalizability of findings, this study nonetheless contributes valuable region-specific data to the existing anatomical literature. Given that genetic, ethnic, and environmental factors may influence nerve topography, region-based studies such as this are essential for improving population-specific surgical safety and enhancing anatomical education in diverse settings[20].

Importantly, this research also highlights the enduring value of cadaver-based anatomical exploration. Formalin-fixed specimens provided clear visibility of the neurovascular structures, though the potential for postmortem shrinkage or structural distortion should be acknowledged as a minor limitation. Despite this, cadaveric dissection remains a cornerstone of anatomical education and a critical tool for refining surgical approaches and training[21].

CONCLUSION

This cadaveric study demonstrated that 40% of dissected adult human hands displayed anatomical variations in the course and branching of the median and ulnar nerves in the palm. These deviations bear substantial clinical relevance, particularly for hand surgeons and anesthesiologists. Early identification and understanding of such patterns can significantly reduce the risk of iatrogenic injuries, improve surgical outcomes, and enhance the precision of regional nerve blocks. The findings underscore the importance of incorporating detailed anatomical assessments into routine surgical planning and highlight the need for larger, population-specific studies to further expand the anatomical database for safer clinical practice.

Data Availability Statement: The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions: S.A. conceptualized the study and supervised the dissections. S.Z. and A.W. performed the cadaveric dissections and data collection. N.F. and U.A. carried out morphometric measurements and photographic documentation. A.A. conducted data analysis and contributed to manuscript writing. All authors reviewed and approved the final manuscript.

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