



A Cadaveric Morphometric Study of the Median Nerve and its Thenar Branch: Surgical Implications for Carpal Tunnel Release

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KEYWORDS

Anatomical variation, Carpal tunnel syndrome, Median nerve, Recurrent thenar branch, Surgical anatomy.

ABSTRACT:

Introduction: The median nerve's anatomy within the carpal tunnel is notoriously variable. A comprehensive understanding of these variations, particularly of the recurrent thenar branch, is crucial to avoid iatrogenic injury during surgical procedures like carpal tunnel release.

Objectives: This study aimed to document the anatomical variations of the median nerve in the carpal tunnel and hand.

Methods: This descriptive cadaveric study was conducted on 56 embalmed adult hands. Dissections were performed to expose the median nerve from the distal forearm to its terminal branches in the palm. The branching pattern, number, origin, and course of the thenar motor branch were observed, photographed, and classified according to Lanz and Poisel.

Results: Standard anatomy was observed in 44.64% (25/56) of hands. Variations were present in 55.36% (31/56). A single thenar branch was found in 76.79% of hands, while 23.21% had multiple branches. The thenar branch was extra ligamentous (Lanz '0') in 60.47% and subligamentous (Lanz '1A') in 39.53% of hands with a single branch; no transligamentous branches were observed. The branching pattern was bifurcating in 67.86% and trifurcating in 32.14%. A communicating branch to the ulnar nerve was found in 25% of specimens.

Conclusions: Anatomical variations of the median nerve are highly prevalent. The significant occurrence of multiple thenar branches and subligamentous courses poses a substantial risk of iatrogenic injury during carpal tunnel surgery. Preoperative awareness and meticulous surgical technique are imperative for preventing complications.

1. Introduction

Carpal Tunnel Syndrome (CTS) is the most common entrapment neuropathy of the upper limb, often requiring surgical intervention via carpal tunnel release (CTR). The success of this procedure hinges on a detailed understanding of the median nerve's anatomy within the carpal tunnel, which is known to be highly variable [1, 2].

The recurrent thenar motor branch, responsible for the innervation of the thenar muscles, is particularly susceptible to injury during CTR. Variations in its origin, number, and course relative to the transverse carpal ligament (TCL) can lead to incomplete release or

permanent motor deficit if inadvertently severed [3, 4]. Classifications by Lanz [5] and Poisel [6] have been pivotal in categorizing these variations, highlighting their clinical significance.

While numerous studies have documented these variations, their reported prevalence varies widely across different populations [7, 8]. This cadaveric study was undertaken to systematically document the anatomical variations of the median nerve and its thenar branch in a sample of the Indian population, providing data crucial for enhancing the safety and efficacy of surgical procedures in the carpal tunnel.



2. Objectives

The primary aim of this cadaveric study was to systematically document the anatomical variations of the median nerve within the carpal tunnel and its branching pattern in the hand. The specific objectives were to observe and classify variations in the course and branching of the median nerve, with a particular focus on the recurrent thenar branch using established Lanz and Poisel classifications. Furthermore, the study sought to tabulate the incidence of these variations, including the presence of multiple thenar branches and communications with the ulnar nerve, and to correlate the anatomical findings with their clinical significance in preventing iatrogenic injury during surgical interventions such as carpal tunnel release.

3. Methods

The present study was conducted in the Department of Anatomy, Pacific Institute of Medical Sciences, Udaipur, after obtaining institutional ethical clearance. A total of 56 formalin-embalmed adult cadaveric hands (from 28 cadavers: 18 male, 10 female) were dissected over two academic sessions. Cadavers with deformities, putrefaction, or from the pediatric age group were excluded.

Dissections were performed under senior supervision following standard protocols from Grant's Dissector [9]. A standard palmar incision was made. The palmar aponeurosis was reflected, and the flexor retinaculum was identified and incised to open the carpal tunnel. The median nerve was meticulously dissected from its entry into the carpal tunnel to its terminal digital branches.

The following parameters were recorded:

- i. Pattern of median nerve branching (bifurcation/trifurcation).
- ii. Number, site of origin, and course of the thenar motor branch(s), classified by Lanz [5] and Poisel [6].
- iii. Presence of communicating branches with the ulnar nerve.
- iv. Any variations in digital distribution or lumbrical innervation.

All findings were documented with digital photography. Data were tabulated and analyzed using descriptive statistics with Microsoft Excel.

4. Results

Demographic Data and Prevalence of Variations

The study included 56 hands from 28 cadavers (64.28% male, 35.72% female). The standard anatomical pattern of the median nerve was observed in 25 hands (44.64%). Anatomical variations were present in 31 hands (55.36%). Variations were more common in left hands (61.29%) than in right hands (38.71%).

Variations in the Thenar Motor Branch

Number of Branches: A single thenar branch was found in 43 hands (76.79%). Multiple thenar branches were present in 13 hands (23.21%), with 12 having two branches and one having three branches (Table 1).

Table 1: Number of Thenar Branches

Number of Thenar Branches	Number of Hands (n=56)	Percentage
Single	43	76.79%
Two (Multiple)	12	21.42%
Three (Multiple)	1	1.79%

Course of Single Thenar Branches (Lanz Classification): Among the 43 hands with a single thenar branch, 26 (60.47%) had an extraligamentous course (Lanz Group '0'), and 17 (39.53%) had a subligamentous course (Lanz Group '1A'). No transligamentous (Lanz Group '1B') branches were observed (Table 2).

Table 2: Course of Single Thenar Branches (Lanz Classification)

Lanz Group	Course	Number of Hands (n=43)	Percentage
Group '0'	Extraligamentous	26	60.47%
Group '1A'	Subligamentous	17	39.53%
Group '1B'	Transligamentous	0	0%

Site of Origin: For single branches, the most common site of origin was the anterolateral aspect (44.18%). In hands with multiple branches (27 branches total), the majority arose from the antero-medial aspect (55.56%).



Branching Pattern of the Main Median Nerve Trunk

The median nerve exhibited a bifurcating pattern in 38 hands (67.86%). A trifurcating pattern was seen in 18 hands (32.14%). No bifid median nerves were observed.

Innervation Patterns and Neural Communications

- The sensory distribution to the lateral three and a half digits was constant in all 56 hands.
- The first and second lumbricals were supplied by the median nerve in all cases. In one hand (1.79%), the third lumbrical was also supplied by the median nerve.
- A communicating branch (Martin-Gruber) between the median and ulnar nerves was found in 14 hands (25%).

Distribution of Anatomical Variations

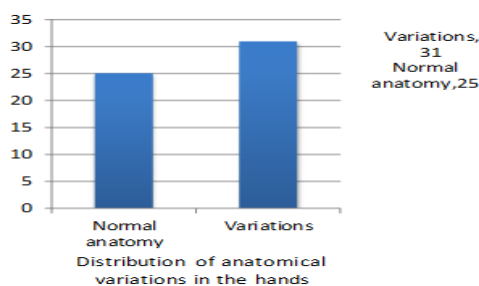


Fig. 1. Bar diagram showing the proportion of hands with normal anatomy versus anatomical variations.

This bar graph illustrates that anatomical variations of the median nerve were more common than the standard anatomy, found in 55.36% of the dissected hands. This high prevalence underscores the importance of surgical awareness.

Variations in Number of Thenar Branches

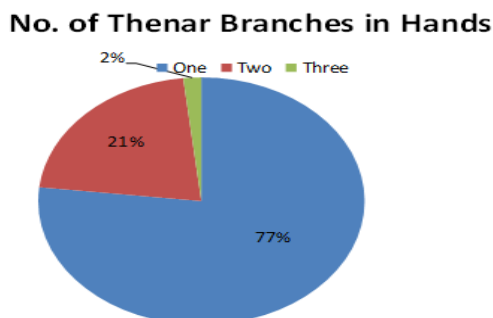


Fig. 2. Pie-chart showing the percentage of hands with single, double, and triple thenar branches.

This pie chart shows that while a single thenar branch was most frequent (76.79%), multiple branches were present in a significant 23.21% of cases. This highlights a key surgical risk, as accessory branches are vulnerable to injury.

5. Discussion

Our study confirms a high prevalence (55.36%) of anatomical variations of the median nerve in the carpal tunnel, consistent with previous reports like Alizadeh et al. (78%) [10], though higher than some such as Beris et al. (10%) [11]. This disparity may be due to ethnic differences or sample size.

A key finding was the absence of the transligamentous thenar branch (Lanz 1B), a high-risk variant for surgical injury. This contrasts with studies like Falconer et al. [12] but aligns with Imamura K [13] and Kozin [14], suggesting its prevalence may be population-specific.

The high incidence of multiple thenar branches (23.21%) is surgically critical. As noted by Hurwitz [15], failure to identify and release all branches can lead to incomplete decompression and symptom recurrence. The common origin of these branches from the antero-medial aspect of the nerve increases their vulnerability during standard surgical approaches.

The 25% incidence of median-ulnar communications is another vital finding. These connections are at risk during extended divisions of the flexor retinaculum in endoscopic procedures, potentially leading to sensory deficits.

Our study's strengths include systematic dissection and classification. The main limitation is the sample size (n=56), which may explain the non-observation of rarer variants like the bifid median nerve.

Clinical Implications: The high prevalence of subligamentous and multiple thenar branches demands meticulous surgical technique during CTR. Surgeons must anticipate these variations, particularly branches arising from the medial side of the nerve, to avoid iatrogenic injury.

Conflict Of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. No financial or



personal relationships with other people or organizations have inappropriately influenced this work.

Limitations

While this study provides valuable insights, certain limitations must be acknowledged. The primary limitation is the relatively small sample size of 56 hands, which may limit the generalizability of our findings and account for the non-observation of rarer anatomical variants, such as the bifid median nerve or transligamentous (Lanz 1B) thenar branches. Furthermore, the study was conducted on a formalin-embalmed cadaveric population, which, while standard for anatomical research, may not perfectly reflect the tissue characteristics and spatial relationships found in living patients. Finally, the study is descriptive and morphological; it does not correlate the anatomical findings with clinical symptoms or surgical outcomes.

6. Conclusion

This cadaveric study demonstrates that anatomical variations of the median nerve in the carpal tunnel are the rule rather than the exception. The significant occurrence of multiple thenar branches and subligamentous courses presents a clear challenge during CTR. A thorough knowledge of this complex and variable anatomy is not merely academic but is essential for planning safe surgical incisions, performing complete decompression, avoiding nerve injury, and ultimately optimizing patient outcomes. Anatomical education and surgical training must continue to emphasize these potential variations.

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