Original research article

# A Study to Analyse of Shape, Amplitude of CMAP of Both Median and Ulnar Nerves and Analysis of Anatomical Innervations of Small Muscles of Hand.

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**Abstract**

**Aim:** the aim of this study was to analyze shape, amplitude of CMAP of both median and ulnar in normal population and to analyze the anatomical innervations of small muscles of hand in normal cadavers.

**Material and methods:** This was retrospective observational study Department of Physical Medicine and Rehabilitation Anugrah Narayan Magadh Medical College, Gaya, India for one year. 200 normal subjects (60 males and 140 females) were include in this study. Motor conduction studies of both median and ulnar nerves were done for the included subjects. Nehon Coden machine was used to conduct the tests. Analysis of the shape of CMAP, amplitude and distal latency were performed. **Results:** 70 percent of the studied subjects were females, while male constituted only 30% with significant difference between both sexes. The mean age of the studied subjects was 38.21 ± 9.1 (age range 18-70). The mean amplitude of median nerve (12.34 mv) was significantly higher than that of the ulnar nerve (11.12 mv) .The mean DL of the median nerve (3.42 msec) was significantly longer than that of the ulnar nerve (2.75 msec). The median nerve CMAP was mostly dome shaped, rather than double peaked. Whereas CMAP of the ulnar was more frequently non dome i.e double peaked, rather than dome shaped. There were no statistical significant differences between the amplitude of dome shaped CMAP and double peaked CMAP in either median or ulnar nerves. The APB received nerve supply from the median nerve in 87% of the specimens and double innervations from both median and ulnar nerves in 13% of the specimens. Flexor pollicis brevis (FPB) received nerve supply from the median nerve alone in 42% of the specimens and from the ulnar nerve alone in 11% of the specimens. FBP received innervations from both nerves median and ulnar in 47% of specimens. Abductor digiti minimi (ADM) muscle received one branch from deep branch of the ulnar nerve in 88% of the specimens and from superficial branches of the ulnar nerve in 12% of the specimens. **Conclusion:** The configuration of the CMAP of the median nerve is mostly dome, whereas that of the ulnar is mostly double peaked. Variability in the pattern of innervations of the small muscle of the hand could be a possible etiological factor.

**Keywords**: CMAP, APB, ADM

## Introduction

The diameter of the peripheral motor nerve gradually decreases until it reaches the target after leaving the spinal cord.[1] In myelinated nerve fibers, the diameter of the nerve fiber is directly proportional to the nerve conduction velocity.[1] Hence, the conduction velocity decreases with the diameter.[1] In contrast, there have also been trials suggesting that there is no difference between the proximal and the distal segment.[2] The motor unit size and the nerve fiber diameter correlate with the size of the muscle they innervate.[3,4] Therefore, it might be predictable that the nerve fibers of muscles with larger mass and proximal localization are larger and faster.[5] A single peripheral nerve stimulates many muscles and, in the same peripheral nerve, nerve fibers can innervate different muscle ends at different levels. The diameters of the most rapidly conducting fibers differ among the most rapidly conducting nerve fibers innervating a proximal muscle, which has a larger diameter compared to those nerve fibers innervating a distal muscle.[4,6] Consequently, if a nerve is stimulated from the same region and an electrophysiological recording is conducted in one proximally and another distally located muscle, data can be obtained about the conduction parameters of the nerve fibers of various diameters.[7] The abductor pollicis brevis (APB) muscle is supplied mainly by the recurrent branch of the median nerve or the lateral terminal branch of the median nerve.[8] However, it can be supplied by the ulnar nerve or receive dual innervations from the median and ulnar nerves.[9] The nerve supply of flexor pollicis brevis muscle is subject to more variations than that of any other muscle in the body. It can be supplied by the median nerve, ulnar nerve or both nerves.[10] The abductor digiti minimi (ADM) muscle is supplied mainly by the deep branch of the ulnar nerve.[11] It may receive innervations from the superficial branch of the ulnar nerve, together with the third and fourth lumbricals.[11] The lumbricals classic innervations originate from the median nerve for the lateral two muscles and from the deep branch of the ulnar nerve for the medial two muscles but considerable variations exist. The 3rd and 4th lumbricals may receive nerve supply from the superficial division of the ulnar nerve.[12] the aim of this study was to analyse of shape, amplitude of CMAP of both median and ulnar nerves and analysis of anatomical innervations of small muscles of hand.

## Material and methods

This was retrospective observational study Department of Physical Medicine and Rehabilitation Anugrah Narayan Magadh Medical College, Gaya, India for one year, after taking the approval of the protocol review committee and institutional ethics committee.

## Methodology

200 normal subjects (60 males and 140 females) were include in this study. Motor conduction studies of both median and ulnar nerves were done for the included subjects. Nehon Coden machine was used to conduct the tests. Surface recording using round silver 1×1 cm in diameter electrodes. The electrodes were applied to the skin through the use of collodion after cleansing of the skin with alcohol prior to application.[13] The standardized motor conduction study of median nerve was done. The conventional sites of stimulation at wrist, elbow, axilla and Erb's point were done, with recording from APB, active electrode over motor point and reference electrode over the tendon. The ground electrode was placed between active and stimulating electrodes.[13] similarly, routine motor conduction study of the ulnar nerve was carried out with stimulation at multiple sites; wrist, below elbow, elbow, above elbow and Erb's point. Recording from ABD was done with active electrode over motor point and reference electrode over the tendon. The ground electrode was placed between active and stimulating electrodes.[13] Those who had normal motor conduction study of both median and ulnar nerves were included in the study. Analysis of the shape of CMAP, amplitude and distal latency were performed.

The study was carried out on 20 cadavers, both sides were dissected. The median and ulnar nerves were exposed and dissected as they enter and supply the muscles of the hand. All the muscular branches of both nerves were identified and followed out throughout their course. The number of these branches and their points of entry into the muscles were identified as well as the connecting loops between the median and ulnar nerves.

## Statistical analysis

Statistical analysis was done using Statistical Package for Social Sciences (SPSS/version 20) software. Arithmetic mean, standard deviation, for numerical data t-test was used to compare between two groups. While for categorical data, chi square test was used. The level of significant was 0.05.

**Results**

70 percent of the studied subjects were females, while male constituted only 30% with significant difference between both sexes (Table 1). The mean age of the studied subjects was 38.21 ± 9.1 (age range 18-70). The mean amplitude of median nerve (12.34 mv) was significantly higher than that of the ulnar nerve (11.12 mv) (Table 2).

**Table 1: Sex distribution of the studied subjects**

| **Gender** | **Number and percentage** | **Significance** |
|---|---|---|
| Male | 60(30%) | Z-test 12.8 |
| Female | 140(70%) | p 0.0001* |

*Significant p ≤ 0.05

**Table 2: Comparison between median and ulnar nerve regarding DL, amplitude and shape of CMAP**

| | | **Mean** | **SD** | **T** | **p** |
|---|---|---|---|---|---|
| Amplitude | Median Amp. | 12.34 | 5.24 | 5.55 | 0.0001* |
| | Ulnar Amp. | 11.12 | 3.12 | | |
| D.L. | DL median | 3.42 | 0.49 | 12.88 | 0.0001* |
| | DL ulnar | 2.75 | 0.48 | | |
| Shape | | Frequency | Percent | Z test | p |
| | Median | | | | |
| | Dome | 140 217 | 70 male | 12.33 | 0.0001* |
| | Non-dome | 60 83 | 30 female | | |
| | Ulnar | | | | |
| | Dome | 30 34 | 15 | | |
| | Non-dome (doublepeaked) | 170 266 | 85 | 19.31 | 0.0001* |

*Significant p ≤ 0.05, Abbreviations: Amp: Amplitude; DL: Distal Lateney; SD: Standard Deviation

The mean DL of the median nerve (3.42 msec) was significantly longer than that of the ulnar nerve (2.75 msec) (Table 2). The median nerve CMAP was mostly dome shaped, rather than double peaked. Whereas CMAP of the ulnar was more frequently non dome i.e double peaked, rather than dome shaped (Table 2).
Mean DL of median nerve was significantly longer in those with dome shaped CMAP rather than those with double peaked CMAP. Mean DL of ulnar nerve was significantly longer in those with dome shaped CMAP rather than those with double peaked CMAP (Tables 3 and 4).

**Table 3: Relation between shape of CMAP of median nerve and DL and Amplitude**

| | | **N** | **Mean** | **S.D.** | **Min.** | **Max.** | **t** | **p** |
|---|---|---|---|---|---|---|---|---|

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| DL median | Non dome | 60 | 3.33 | 0.45 | 2.7 | 4.1 | 5.15 | 0.002* |
| | Dome | 140 | 3.47 | 0.46 | 2.8 | 4.2 | | |
| Median amp. | Non dome | 60 | 11.06 | 4.52 | 5.3 | 21.6 | 2.74 | 0.111 |
| | Dome | 140 | 12.12 | 5.22 | 4.1 | 25.1 | | |

**Table 4: Relation between shape of CMAP of ulnar nerve and DL and Amplitude**

| | | **N** | **Mean** | **S.D.** | **Min.** | **Max.** | **t** | **p** |
|---|---|---|---|---|---|---|---|---|
| DL ulnar | Non dome | 170 | 2.72 | 0.41 | 1.6 | 4.2 | 3.82 | 0.0001* |
| | Dome | 30 | 2.97 | 0.52 | 2.1 | 3.7 | | |
| amp ulnar | Non dome | 170 | 10.62 | 2.84 | 6.1 | 18.9 | 0.93 | 0.321 |
| | Dome | 30 | 10.12 | 4.65 | 3.7 | 16.6 | | |

There were no statistical significant differences between the amplitude of dome shaped CMAP and double peaked CMAP in either median or ulnar nerves (Tables 3 and 4). The APB received nerve supply from the median nerve in 87% of the specimens and double innervations from both median and ulnar nerves in 13% of the specimens (Table 5).

**Table 5: Nerve supply of the muscles of the thenar muscles.**

| | **Median nerve** | **Ulnar nerve** | **Both** |
|---|---|---|---|
| Flexor pollicis brevis | 42% | 11% | 47% |
| Abductor pollicis brevis | 87% | 0% | 13% |
| Opponens pollicis | 78% | 11% | 11% |
| Adductor pollicis | 0% | 88% | 12% |

The patterns of innervations of APB from the median nerve were different (Table 6). Usually, the branches supplying the muscle from the recurrent branch, lateral division or both are close to each other. Infrequently, APB received branches distant from each other .

**Table 6: Pattern of nerve supply of abductor pollicis brevis muscle.**

| **Number of muscular branches from the median nerve** | **%** | **origin** | **Point of entry** |
|---|---|---|---|
| One branch | 25% | Recurrent 15%-Lateral division 15% | Near the origin Into the middle of the muscle |
| Two branches | 45% | Lateral division | One branch near the origin. The other branch into the middle of the muscle |
| Three branches | 35% | One from the recurrent. Two from the lateral division | Enter near the origin. One enters the middle of the muscle-The other branch enters near the insertion |

Table 5 presented that flexor pollicis brevis (FPB) received nerve supply from the median nerve alone in 42% of the specimens and from the ulnar nerve alone in 11% of the specimens . FBP received innervations from both nerves median and ulnar in 47% of specimens .
Abductor digiti minimi (ADM) muscle received one branch from deep branch of the ulnar nerve in 88% of the specimens and from superficial branches of the ulnar nerve in 12% of the specimens (Table 7).

**Table 7: Nerve supply of the muscles of the hypothenar muscles**

| | Deep branch of ulnar nerve | Superficial branch of ulnar nerve |
|---|---|---|
| Flexor digiti minimi brevis | 88% | 12% |
| Abductor digiti minimi brevis | 88% | 12% |
| Opponens digiti minimi | 100% | 0% |

Simultaneous branches from the deep branch of the ulnar nerve to 3rd lumbrical muscle (75% of the specimens) and to 4th lumbrical muscles(100% of the specimens) and to the palmar interossei in all the specimens (Table 8) .

**Table 8: Nerve supply of the lumbrical muscles**

| | Median nerve | Ulnar nerve | Both |
|---|---|---|---|
| 1st lumbrical | 96% | 0% | 4% |
| 2nd lumbrical | 82% | 18% | 0% |
| 3rd lumbrical | 25% | 75% | 0% |
| 4th lumbrical | 0% | 100% | 0% |

**Discussion**

In the present study, mean median nerve amplitude was (12.34 mv) significantly higher than that of ulnar nerve (11.12 mv). Both Kimura[13] and Dumitru[14] found similar findings. They reported mean median amplitude was 13.2±5 mv, 7±3 mv respectively. That of ulnar nerve was 6.1±1.9 mv, 5.7±2 mv respectively. Hennessey, et al. [14] found the ulnar nerve amplitude (12.6 ± 2.3 mv) slightly higher than that of median nerve. However, he did not mention whether these differences were significant and there is no definite explanation .[15]The variability in the values of the mean amplitude of both nerves from one series to another could be secondary to racial difference. Weber [16] suggested that generally, the amplitude of the CMAP is dependent upon the synchronization of the signal's arrival. The more synchronized the signal, the greater (more spike like) the amplitude. Thus amplitude varies inversely with the dispersion of the evoked response[16] Since we found that CMAP of the median nerve is more frequently higher than that of the ulnar nerve. We could speculate that the synchronization of the median nerve is usually more than that of the ulnar nerve.
Also in the present study, the median nerve CMAP of was mostly dome shaped and that of the ulnar nerve was mostly double peaked. This also could be explained in light of Weber suggession.[16] Dumitru[14] and Kimura[13] mentioned that the shape of CMAP is biphasic curve. They did not mention the frequently encountered difference in the shape of CMAP between the median and the ulnar nerve.[13,14] Bromberg and Spiegellerb [17]studied the influence of the active electrode placement on CMAP amplitude and concluded that in order to record the maximal CMAP response, empirical assessment by moving the active electrode is necessary[17] In our study, we had placed the active electrode over the standardized motor points for the

abductor pollicis brevis and the abductor digiti minimi muscle for all the studied subjects so we have eliminated the influence of changing electrode placement on CMAP amplitude.
Similarly, Lateva, et al.[18] concluded that CMAP shape is related to electrode configuration and anatomical factor particularly muscle fiber length that changes with changes of thumb position.[18] These factors for changes in CMAP configuration are not applicable to our study since we used fixed standardized techniques and same electrode placement for all the studied subjects without any movement of the thumb or the little finger.
Kincaid, et al.[19] suggested that the tendon sites are not electrically inactive. The ulnar tendon electrode contribute to large extent to the second peak of CMAP i.e tendon potential. While the median tendon electrode contribute only minimally to the negative phase of the CMAP.[19] However in our study we did not record from tendon sites.
Van Dijk, et al.[20] maped the spatial and temporal dispersion of CMAP. They concluded that wave form difference are due to difference in muscle architecture and variability.[20] Moreover, our anatomical results showed that APB received mostly innervations from median nerve only. Those branches from median nerve are very close to each other from the lateral division or only one branch from the recurrent branch. Homma and Sakai[21] agreed with these anatomical results and mentioned that the APB has a separate belly and receives separate nerve branch.[21] Ajmani[11] found in his series that APB muscle supplied by median nerve alone.[11] These anatomical findings could be a possible explanation of the frequently encountered dome shaped CMAP of the median nerve i.e Why it is synchronized.
On the other hand, our anatomical results showed that abductor digiti minimi receives one branch from the deep branch of the ulnar nerve in 88% of cases. Simultaneous branches from deep branch of the ulnar nerve arise to 3rd lumbrical (75% of cases).
The 4th lumbrical (100% of cases) as well as palmar interossei. Revising literature in this context found similar results.[21,22] Ajmani[12] reported that the deep branch alone supplies the abductor digiti minimi. It also supplies the third and forth lumbricals in 94% of his series.[12] Our findings that the ulnar CMAP is typically double peaked could be explained in light of the anatomical findings of simultaneous branches that arise from deep branch of ulnar nerve to ADM, 3rd, 4th lumbricals and palmar interossei. So the second peak of the curve could be from volume conduction from those muscles.
Mc Gill and Lateva[23]concluded that the first peak of the negative phase of CMAP comes from the hypothenar muscles but the second peak is due to large volume conducted potential from the interosseous muscle. The interosseous contribution affects both the amplitude and the area of CMAP. However this contribution is sensitive to finger movement and temperature changes of the hand.[23] In our study, these factors are not applicable, so the anatomical explanation might be more possible.
Little percentage of the studied subjects showed double peaked CMAP of the median nerve. In light of the anatomical results, The APB received nerve supply from the median nerve in 87% of the specimens and double innervations from both median and ulnar nerves in 13% of the specimens. Also infrequently APB supplied by branches distant from each other from recurrent and lateral division of the median. Similar anatomical results were recorded by Mumford and Olave.[24,25] In addition, flexor pollicis brevis which is anatomically very close to APB was found in our series to receive double innervations from the median and ulnar nerves in 47% of the examined cadavers. Lo Monaco, et al.[26] agreed with these findings. These occasional anatomical findings in our series as well as in the previous literature could be a possible etiological factor for the infrequently encountered double peaked CMAP of the median nerve. In addition, ulnar to median nerve anastomosis which was found in some of our cadavers could also be possible etiologic factor. Definite etiological factor could not be detected because we could not dissect the hands of the normal studied subjects to detect the exact pattern of innervations of the thenar muscles.

Similarly, we found that in 12% of the studied cadavers, the ADM supplied by superficial branch from ulnar nerve solely. These minority of anatomical findings could be a possible etiological factor for the rarely met dome shaped CMAP of ulnar nerve.

In the present study, the mean DL of the median nerve was significantly longer than that of the ulnar nerve. There is no comment on these findings in the literature. However, Weber[16] suggested that generally, the latency depend upon number of different physiologic events; latency of activation; the time between the initiation of electrical discharge in the stimulator and the actual beginning of salutatory conduction along the axon, fast salutatory along the large myelinated axon. Slower conduction along the smaller diameter of the myelinated axon as it tapers distally. Very slow conduction along the non myelinated terminal twigs of axon.[16]

Since we found that the median nerve CMAP was mostly dome shaped i.e. has better synchronization of different nerve fibers. So we could explain the longer distal latency of median nerve compared with that of ulnar nerve, because of many synchronized fibers with different conduction velocity contribute to compound muscle action potential. Hence, longer latency. Whereas, the ulnar nerve has frequently double peaked CMAP together with shorter latency compared with median nerve. This is mostly because less synchronization of fibers, hence latency could be depending mainly on the fastest conducting fibers only i.e short latency.In addition, among each individual nerve whether median or ulnar nerve, we found that the distal latency of each nerve is significantly longer in case that CMAP shape is dome and shorter in case that CMAP is double peaked. This also supports our explanation which suggest the relationship between synchronization of CMAP and latency.

## Conclusion

The configuration of the CMAP of the median nerve is mostly dome, whereas that of the ulnar is mostly double peaked. Variability in the pattern of innervations of the small muscle of the hand could be a possible etiological factor

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