Review Papers: Variations of Median Nerve from Axillary Region to Cubital Fossa

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ABSTRACT

Introduction: Median nerve (MN), one of terminal branches of brachial plexus, is commonly associated with several variations. This research aimed to review the literature related to the variations of MN from axillary region to cubital fossa.


Results: Variations in the origin, communication with other nerves, region of formation, pattern of innervations, and story of MN are common. MN in cases with abnormal origination forms by 3 roots (91.1%), 4 roots (7.5%), and 1 root (1.2%). The most common variation of MN has been detected in its communication with other nerves. These types of variations include 1 communication between MN and musculocutaneous nerve (MCN) (80.2%), 2 communications between MN and MCN (6%), fusion of MN with MCN (6.3%), and communication with other nerves (7.3%). The unusual regions of MN formation include arm (60.5%), medial to axillary artery (34.6%), and posterior to axillary artery (4.8%). Anterior compartment of arm and lateral side of forearm are either completely (45.8%) or partially (43.7%) the abnormal pattern of MN innervation. Other variations in MN innervation form 10.4% of cases. Entrapment (57.5%) and non-entrapment (42.4%) forms are 2 types of MN story variations.

Conclusion: The knowledge of these variations is crucial for medical experts such as anesthesiologists, radiologist, surgeons, neurophysiologists, and electromyographists to accomplish their duties properly.


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1. Introduction

Median nerve (MN) is one of the terminal branches of the brachial plexus (BP). It is normally formed by union of lateral (C5, C6, C7) and medial (C8, T1) spinal roots, which arise from lateral and medial cords of BP. These roots fuse together at anterior or lateral side of the third part of the axillary artery to form MN [1]. At first, the nerve passes lateral to brachial artery and then near the insertion of coracobrachialis muscle (CBM) where it most often crosses in front of or rarely behind the artery, going down medial to it to cubital fossa where it passes anterior to brachial muscle and posterior to the bicipital aponeurosis. Typically, this nerve has no branches in the axilla or the arm [2]. MN is commonly associated with several variations, which include abnormalities in origination [3-8], communication with other branches of BP [9-11], region of formation [12-15], pattern of innervations in arm [16-19], and its course to cubital fossa [20-23]. Therefore, descriptions of these variations are useful for anatomists, radiologists, and surgeons to perform surgical procedures, as well as to improve ability of anesthesiologists guiding needle to nerve without danger [24, 25]. This article aimed to review the literature on these variations of MN from axillary region to cubital fossa.

2. Materials and Methods

We searched Google Scholar, Science Direct, Springer, and PubMed electronic databases to compile case reports and review articles related to the variation of MN published from 1990 to 2015 using the following key terms: “median nerve”, “brachial plexus”, “ulnar nerve”, and “musculocutaneous nerve”. Each of these heads was then combined with the MeSH terms “anatomy”, “anomaly”, and “variation”. All the cases chosen for this article are from dissectional observation except one observation in which a rare variation was presented (Kazuki, 2004).

3. Results

Variation in the formation of MN

Total number of cases in which MN is formed with more or less than 2 roots are 158 cases (Table 1):

- MN forms by 3 roots in 144 cases (91.1%),
- MN forms by 1 root in 2 cases (1.2%),
- MN forms by 4 roots in 12 cases (7.5%).

Out of 158 cases

Arterial anomaly is reported in one case:

depth brachial artery originate from posteromedial aspect of brachial artery [15].

Neural variation is reported in 3 cases

Lateral cord of BP pierce the CBM in two cases [30, 37] and Ulnar nerve (UN) has communication with anterior division of middle trunk in one case [7].

Variation of MN in communication with other branches of BP

Total number of cases in which MN has communicated with other branches of BP is 365 cases (Tables 2, 3):
• MN had 1 communicating branch with musculocutaneous nerve (MCN), reported in 293(80.2%) cases,
• MN had 2 communicating branch with MCN, reported in 22(6%) cases,
• MN fused with MCN completely or for some distance reported in 23(6.3%) cases,
• MN had communication with other branches of BP except MCN, reported in 27(7.3%) cases.
• MN had 2 associated communication variation on the same side, which was reported in 4 cases [41-43]. We mentioned them separately in 4 categories and then analyzed their information.

Out of 366 cases
Vessels anomaly was reported in 5 cases
• Axillary artery divided into superficial and definitive brachial artery was reported in 1 case [49],
• Superficial brachial artery originated from axillary artery was reported in 1 case [47],
• Persistent median artery originated from ulnar artery was reported in 1 case [53],
• Brachial artery divided into radial artery and ulnar artery in arm was reported in 1 case [54],
• One of brachial veins course between MN and communicating branch from MCN was reported in 1 case [45],
• Muscular anomaly was reported in 1 case:
  • Biceps muscle has an accessory head [9].
• Neural variation was reported in 2 cases:
  • Lateral cord of BP innervated the CBM was reported in 1 case [47],
  • UN had communication with radial nerve and posterior cord of BP was absent [11].

**Table 2.** MN communications with other branches of BP.

<table>
<thead>
<tr>
<th>Type of communication</th>
<th>Total number</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two communicating branches with MCN</td>
<td>22(6%)</td>
<td>IWAMOTO, 1990 [59]; Choi, 2002 [42]; Chauhan, 2002 [60]; Arora, 2003 [61]; Loukas, 2005 [50]; and Indrasingh, 2014 [9]</td>
</tr>
</tbody>
</table>

**Table 3.** MN communications with other branches of BP except MCN.

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of cases</th>
<th>Brief explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramachandran, 2007 [41]</td>
<td>1</td>
<td>Lateral root of MN has communication with UN</td>
</tr>
<tr>
<td>Sontakke, 2011 [33]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Chaudhary, 2013 [43]</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Badawoud, 2003 [48]</td>
<td>4</td>
<td>There is interconnection between roots of MN</td>
</tr>
<tr>
<td>Nene, 2010 [14]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Darji, 2013 [57]</td>
<td>3</td>
<td>There is multiple interconnection between roots of MN</td>
</tr>
<tr>
<td>Uzun, 1999 [38]</td>
<td>14</td>
<td>Medial root of MN has communication with anterior division of middle trunk</td>
</tr>
<tr>
<td>Satyanarayana, 2009 [32]</td>
<td>1</td>
<td>MN receive communicating branch from lateral cord</td>
</tr>
</tbody>
</table>
Variation in region of MN formation

Total number of cases in which MN forms in irrespective region was reported in 104 cases (Table 4):

- MN formed in arm was reported in 63 (60.5%) cases,
- MN formed in medial to axillary artery was reported in 36 (34.6%) cases,
- MN formed in posterior to axillary artery was reported in 5 (4.8%) cases.

Variation in innervation pattern of MN

Total number reported cases in which MN had abnormal pattern of innervations was 48 cases (Tables 5, 6):

- MN innervated anterior compartment of arm and lateral side of forearm was reported in 22 (45.8%) cases,
- MN innervated anterior compartment of arm and lateral side of forearm except CBM was reported in 21 (43.7%) cases,
- Other variation in innervation pattern of MN was reported in 5 (10.4%) cases.

Out of 48 cases

Arterial anomaly was reported in 2 cases

Table 4. MN formation in irrespective regions.

<table>
<thead>
<tr>
<th>Region of formation</th>
<th>Number of cases</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior to axillary artery</td>
<td>5 (4.8%)</td>
<td>Haviarova, 2001 [68]; Haviarova, 2009 [2]; Nene, 2010 [14]; and Nene, 2010 [69]</td>
</tr>
</tbody>
</table>

Table 5. Various innervation pattern of MN.

<table>
<thead>
<tr>
<th>Region of innervations by MN</th>
<th>Number of cases</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior compartment of arm and lateral side of forearm except CBM</td>
<td>*21 (43.7%)</td>
<td>Gümüşburun, 2000 [72]; Beheiry, 2004 [49]; Pacholczak, 2011 [73]; Budhiraja, 2011 [52]; Bhanu, 2012 [35]; Sushma, 2013 [74]; and Zhang, 2014 [16]</td>
</tr>
</tbody>
</table>

* Lateral cord of BP innervate CBM in these cases.

Table 6. Other various innervation pattern of MN.

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of cases</th>
<th>Brief explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indrasingh, 2014 [9]</td>
<td>1</td>
<td>MN innervate brachialis muscle and lateral side of forearm</td>
</tr>
<tr>
<td>Tatar, 2004 [75]</td>
<td>1</td>
<td>Lateral root of MN innervate CBM</td>
</tr>
<tr>
<td>Tomar, 2012 [54]</td>
<td>1</td>
<td>MN innervate the CBM</td>
</tr>
<tr>
<td>Gümüşalan, 1998 [76]</td>
<td>1</td>
<td>MCN arise from lateral root of MN</td>
</tr>
</tbody>
</table>
scending branch of profunda brachii artery was reported in 1 case [74].

- Muscular anomaly was reported in 2 cases:
  - Biceps brachii had an accessory head in these 2 cases [73, 74].

- Neural variation was reported in 42 cases:
  - Absence of MCN was reported in 40 cases [5, 16-18, 22, 33, 35, 46, 49, 52, 65, 70-74].
  - MCN did not pierce the CBM was reported in two cases [62, 76].
  - Long thoracic nerve originated from C5, C6 was reported 1 case and MN had communication with UN in forearm was reported in 2 cases (in same cases in which MCN was absent) [72].

#### Variation in course of MN

Total number of cases in which MN had abnormal course and story were 33 cases (Tables 7, 8):

- MN might be entrapped was reported in 19(57.5%) cases,
- Other variations in course and story of MN were reported in 14(42.4%) cases.

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of cases</th>
<th>Brief explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satyanarayana, 2009 [32]</td>
<td>1</td>
<td>MN passes behind the brachial artery</td>
</tr>
<tr>
<td>Haviarova, 2001 [68]</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pandey, 2007 [67]</td>
<td>4</td>
<td>Roots of MN do not fuse together and pass anteromedial to brachial artery separately</td>
</tr>
<tr>
<td>Kumari, 2015 [6]</td>
<td>1</td>
<td>MN does not cross from lateral aspect of brachial artery to medial</td>
</tr>
<tr>
<td>Budhiraja, 2011 [52]</td>
<td>6</td>
<td>MN divide into 2 branches in arm</td>
</tr>
</tbody>
</table>

### Table 8. Other variations in the course and story of MN.

#### Table 7. Entrapment associated variations.

<table>
<thead>
<tr>
<th>Type of anomaly</th>
<th>Number of cases</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone associated variation</td>
<td>1(2.9%)</td>
<td>Kazuki, 2004 [77]</td>
</tr>
<tr>
<td>Ligament and sheath associated variation</td>
<td>7(20.5%)</td>
<td>Gunther, 1993 [81]; Nakatani, 1997 [62]; Wadhwa, 2004 [82]; Bilecenoglu, 2005 [78]; and Rodrigues, 2008 [83]</td>
</tr>
</tbody>
</table>
Based on the roots union to form MN, different abnormal formations are reported by many authors [7, 29, 37, 39, 40]. Lateral cord is the most common cord of BP which gives extra root of this abnormal formation [4, 15, 32-34]. Interestingly, in cases that MN is formed by 1 root, the lateral cord is the origin of MN [7, 39]. Notably, in cases that MN is formed by 3 roots, the medial root of BP does not give any extra root [36].

Sargon [26] emphasized the crucial role of this type of variation in MN formation and its effect on adjacent tissues such as compressing the bypassing vessel. Therefore, these variations are important in pre-operative precaution.

According to our study, communication between MCN and MN is the most common variation of MN. Venieratos [87] classified communication between MCN and MN according to the location of CBM into 3 groups:

**Type 1:** Communication between MCN and MN proximal to the point of penetration CBM by MCN,

**Type 2:** Anastomosis between MCN and MN distal to location of CBM, and

**Type 3:** Both MCN and communicating branch did not pierce the CBM.

According to another study, communication pattern of MCN and MN was classified into 5 groups [88]:

**Type 1:** There was no communication between MCN and MN,

**Type 2:** The fiber of medial root of MN merged with MCN and MN received anastomotic branch in middle part of upper arm,

**Type 3:** The lateral root of MN joined to MCN and after some distance left it to form MN,

**Type 4:** The MCN fibers passed through the lateral root of MN and after some distance the MCN emerged from the MN,

**Type 5:** MCN was absent and the whole fiber of MCN passed through lateral root of MN, which has all MCN’s branches in upper arm.

Knowledge of this variation can help neurophysicians to diagnose special pattern of muscle weakness after neural dysfunction.

**Figure 1.** Anatomical region of mid humeral BP block method [91].
injury and to interpret the result of neural conduction examination. Electrotherapy in physiotherapy, interpretation of neural radiography in radiology, and post-trauma evaluation of peripheral nerves in the field of trauma surgery are the advantages of attention to these variations [89]. Martin [84] and Gruber [85] were the first observers who described communication between UN and MN. Fazan [13] reported 16 cases in which UN had communication with lateral cord of BP. Fuss [90] reported lateral root of UN (communication of UN with lateral root of MN is called lateral root of UN) in 56% of his dissections. He believed that lateral root of UN should be considered as normal formation of UN. However the results of our review about case reports and dissectional literature did not verify this hypothesis as a quandary belief.

Variations in the region of MN formation are not rare and has been observed and reported by several authors [2, 48, 60]. Detailed information on the various regions of MN formation can be classified into 2 groups: 1) MN is formed distal to respective axillary region [13, 49] and 2) MN is formed in abnormal region to axillary artery [34, 60]. Haviarova [2] agreed with the opinion that variation in the region of MN formation may lead to atypical electromyography finding. Anatomical variation of MN is important for the method of mid humeral BP block. This technique is used to condition which BP block is contraindicated such as coagulopathy and infection. In this method, 4 BP nerves (MN, UN, MCN, and radial) are blocked at the level of mid humerus. Normally, MN is located on the lateral side of brachial artery at this level [91] (Figure 1).

Any variation in the course or region of MN formation can cause possible mistake in this method. Therefore, using ultrasound technique prior to the procedure is highly recommended [91].

Variation of MCN as terminal branch of BP is common and has been reported by several authors [62, 88, 92]. The variations in innervations pattern of MN are correlated to variation of MCN, especially absence of MCN that has been reported by many authors [5, 16, 35]. In the absence of MCN, the MN usually innervates the anterior compartment of arm [18, 65]. CBM as a muscle of anterior compartment of arm is innervated by lateral cord of BP in some cases [19, 72, 74]. Interestingly, MN almost gives lateral cutaneous nerve of forearm in cases in which MCN is absent [9, 17]. Awareness of these variations in innervation pattern of anterior compartment of arm and lateral side of forearm is important, especially in peripheral nerve stimulation studies [18]. These variations of innervations patterns of MN may lead to surgeon’s confusion in post-trauma evaluation.

Many observations were made on the story and course of MN in different studies [78, 79]. Based on the possibility of entrapment, the variations in the course and story of MN can be classified into 2 groups: 1) entrapment associated variations [23, 77] and 2) non-entrapment associated variations [52, 68]. Knowledge of these anomalies, especially entrapment associated variations are clinically important. Entrapment and enfolding of MN by other adjacent structures like accessory head of biceps can cause symptoms similar to pronator teres syndrome as well as neuropathy symptoms such as numbness and paresthesia [23].

Variations of MN and other peripheral nerves can be explained according to the embryologic events. The upper limb buds is formed opposite to lower cervical and upper thoracic segments (C5-T2). Incomplete contact of ventral primary rami of spinal nerves penetrating the mesoderm of buds may lead to variation of BP nerves and MN as its terminal branch. Additionally, circulation associated factors such as trophic agents may be the causality of development anomalies of peripheral nerves [93]. A growth cone is formed at the tip of axon growing to target tissue by sensing tropic molecules secreted by surrounding tissue. Unleveled expression of N-CAM, L1, and cadherins acting as transcription factors and binding to molecules and components of extracellular matrix may lead to abnormal neural development [94].

Variations in BP nerves, especially MN, can be classified according to sex, race, and side of body. However many authors did not report their observations according to side of body, especially in multiple cadaver studies. However, Matejcik reported that majority of BP anomaly are on the right side [95]. Dissection of male cadavers is routine, especially in Muslim countries and we believe that the results of this review might not completely applicable to women.

Variations in MN as a terminal branch of BP are common as we reported in the present study. As other authors emphasized, we believe that knowledge of these variations is crucial for specialties concerned about peripheral nerves in different areas such as anesthesiology, radiology, surgery, neurophysiology, and electromyography.

Acknowledgements

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Conflict of Interest

The authors of this study declared no conflict of interests.
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