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

Milad Behnejad[1], Mohsen Bakhshi Kashi[1], Hossein Nikzad[2*], Aliakbar Taherian[2], Amirhossein Loghman[1]

1. Student Research Committee, Kashan University of Medical Sciences, Kashan, Iran.
2. Anatomical Sciences Research Center, Kashan University of Medical Sciences, Kashan, Iran.

Citation: Behnejad M, Bakhshi Kashi M, Nikzad H, Taherian AA, Loghman AH. Variations of median nerve from axillary region to cubital fossa. Anatomical Sciences. 2016; 13(1): 3-12.

Dr. Hossein Nikzad is the professor in Kashan university of medical sciences. He has been lecturer in anatomy and embryology, clinical and surface anatomy & embryology. His research interests are vasectomy, TEM microscopy, experimental IVF & clinical IVF.

Article info:
Received: 19 Jul. 2015
Accepted: 09 Nov. 2015
Available Online: 01 Jan 2016

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.

Methods: We searched Google Scholar, Science Direct, Springer, and PubMed electronic databases to compile reports related to the variation of MN published from 1990 to 2015.

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.

Key Words:
Brachial plexus,
Variation, Median nerve,
Musculocutaneous nerve

*** Corresponding Author:**
Hossein Nikzad, PhD
Address: *Anatomical Sciences Research Center, Kashan University of Medical Sciences, Kashan, Iran.*
Tel: *+98 (913) 1616689* *Fax: +98 (315) 55621157*
E-mail: *hnikzad@yahoo.com*

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 into cubital fossa where it passes anterior to brachialis 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:

deep 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):

Table 1 . MN from more or less than 2 roots.

Number of roots forming MN	Origin of extra root	Total cases	Authors
Three	Lateral cord	134(84.8%)	Sargon, 1995 [26]; Kabak, 2001 [27]; Fazan, 2003 [13]; Saeed, 2003 [28]; Goyal, 2005 [29]; Jafari Anrkooli, 2007 [30]; Aggarwal, 2009 [31]; Satyanarayana, 2009 [32]; Pais, 2010 [15]; Sontakke, 2011 [33]; Budhiraja, 2011 [34]; Bhanu, 2012 [35]; Ongeti, 2012 [21]; Talhar, 2012 [3]; Rao, 2013 [36]; Ghorai, 2013 ; Itoo, 2014 [4]; Shashanka, 2014 [5]; and Kumari, 2015 [6]
	Anterior division of middle trunk	10(6.3%)	Nakatani, 1998 [37]; Uzun, 1999 [38]; Fazan, 2003 [13]; and Goyal, 2005 [29]
One	Lateral cord	2(1.2%)	Bhanu, 2010 [7]; and Patil, 2012 [39]
Four	Lateral cord	9(5.6%)	Satyanarayana, 2009 [32]; Uzun, 2001 [40]; and Budhiraja, 2011 [34]
	Lateral and medial cord	1(0.6%)	Aggarwal, 2009 [31]
	Not reported exactly	2(1.2%)	Kumari, 2015 [6]

- 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.

Type of communication	Total number	Authors
One communicating branch with MCN	293(80.2%)	Kaus, 1995 [44]; Basar, 2000 [45]; PrasadaRao, 2001 [46]; Sarikcioglu, 2001 [47]; Choi, 2002 [42]; Fazan, 2003 [13]; Saeed, 2003 [28]; Badawoud, 2003 [48]; Beheiry, 2004 [49]; Goyal, 2005 [29]; Loukas, 2005 [50]; Kocabiyik, 2005 [51]; Ramachandran, 2007 [41]; Oluyemi, 2007 [11]; Maeda, 2009 [10]; Nene, 2010 [14]; Budhiraja, 2011 [52]; Agarwa, 2011 [53]; Sawant, 2012 [22]; Patil 2012 [39]; Tomar, 2012 [54]; ElFalougy, 2013 [55]; Kumar, 2013 [56]; Darji, 2013 [57]; and Radunovic, 2013 [58]
Two communicating branches with MCN	22(6%)	IWAMOTO, 1990 [59]; Choi, 2002 [42]; Chauhan, 2002 [60]; Arora, 2003 [61]; Loukas, 2005 [50]; and Indrasingh, 2014 [9]
MN fuses with MCN completely	23(6.3%)	Nakatani, 1997 [62]; PrasadaRao, 2001 [46]; Choi, 2002[42]; Nene, 2010 [14]; Chaudhary, 2013 [43]; and Aggarwal, 2013 [63]

ANATOMICAL SCIENCES

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

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

ANATOMICAL SCIENCES

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.

Table 4. MN formation in irrespective regions.

Region of formation	Number of cases	Authors
Arm	63(60.5%)	Nakatani, 1998 [37]; Kabak, 2001 [27]; Badawoud, 2003 [48]; Fazan, 2003 [13]; Beheiry, 2004 [49]; Aydin, 2006 [17]; Nayak, 2006 [64]; Nayak, 2007 [65]; Satyanarayana, 2009 [66]; Nene, 2010 [14]; Budhiraja, 2011 [34]; Sawant, 2012 [22]; and Parchand, 2013 [18]
Medial to axillary artery	36(34.6%)	Chauhan, 2002 [60]; del Fascículo, 2005 [12]; Pandey, 2007 [67]; Satyanarayana,;2009 [32]; Pais, 2010 [15]; Sontakke, 2011 [33]; Budhiraja, 2011 [34]; and Kumari, 2015 [6]
Posterior to axillary artery	5(4.8%)	Haviarova, 2001 [68]; Haviarova, 2009 [2]; Nene, 2010 [14]; and Nene, 2010 [69]

ANATOMICAL SCIENCES

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

Brachial artery divided into ulnar and radial artery distal to respective region was reported in 1 case [17],

Brachial artery had common trunk for posterior circumflex humeral artery, radial artery and posterior de-

Table 5. Various innervation pattern of MN.

Region of innervations by MN	Number of cases	Authors
Anterior compartment of arm and lateral side of forearm	22(45.8%)	Nakatani, 1997 [62]; Ihunwo, 1997 [70]; Sud, 2000 [71]; PrasadaRao, 2001 [46]; Aydin, 2006 [17]; Nayak, 2007 [65]; Sontakke, 2011 [33]; Parchand, 2013 [18]; Shashanka, 2014 [5]; and Sawant, 2012 [22]
Anterior compartment of arm and lateral side of forearm except CBM	*21(43.7%)	Gümüsburun, 2000 [72]; Beheiry, 2004 [49]; Pacholczak, 2011 [73]; Budhiraja, 2011 [52]; Bhanu, 2012 [35]; Sushma, 2013 [74]; and Zhang, 2014 [16]

*Lateral cord of BP innervate CBM in these cases.

ANATOMICAL SCIENCES

Table 6. Other various innervation pattern of MN.

Author	Number of cases	Brief explanation
Indrasingh, 2014 [9]	1	MN innervate brachialis muscle and lateral side of forearm
Tatar, 2004 [75]	1	Lateral root of MN innervate CBM
Tomar, 2012 [54]	1	
Gümüşalan, 1998 [76]	1	MN innervate the CBM
Suseelamma, 2013 [19]	1	MCN arise from lateral root of MN

ANATOMICAL SCIENCES

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.

Out of 34 cases

Muscular anomaly was reported in 9 cases

- Biceps brachii had an accessory head was reported in 7 cases [20-23, 64, 79],
- Pronator teres had only humeral head was reported in 1 case [78],
- Pronator teres had proximal insertion to respective region was reported in 1 case [81].

Neural variation was reported in 3 cases

- MN pierced the CBM was reported in one cases [14],
- Anterior interosseous originated from MN in arm [81],
- Nerve of pronator teres originated in arm was reported in one case [82].

4. Discussion

Variations in formation, distribution, course, and communication of BP branches and MN as a sensory and motor branch of BP are common and has been reported since 18th and 19th century [84-86].

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

Author	Number of cases	Brief explanation
Satyanarayana, 2009 [32]	1	MN passes behind the brachial artery
Haviarova, 2001 [68]	1	
Shashanka, 2014 [5]	1	
Pandey, 2007 [67]	4	Roots of MN do not fuse together and pass anteromedial to brachial artery separately
Kumari, 2015 [6]	1	MN does not cross from lateral aspect of brachial artery to medial
Budhiraja, 2011 [52]	6	MN divide into 2 branches in arm

ANATOMICAL SCIENCES

Table 7. Entrapment associated variations.

Type of anomaly	Number of cases	Authors
Bone associated variation	1(2.9%)	Kazuki, 2004 [77]
Muscularly associated variation	11(32.3%)	Bilecenoglu, 2005 [78]; Nayak, 2006 [64]; Saralaya, 2009 [79]; Nene, 2010 [14]; Mahato, 2010 [20]; Sawant, 2012 [22]; Ongeti, 2012 [21]; Sawant, 2013 [80]; and Yershov, 2015 [23]
Ligament and sheath associated variation	7(20.5%)	Gunther, 1993 [81]; Nakatani, 1997 [62]; Wadhwa, 2004 [82]; Bilecenoglu, 2005 [78]; and Rodrigues, 2008 [83]

ANATOMICAL SCIENCES

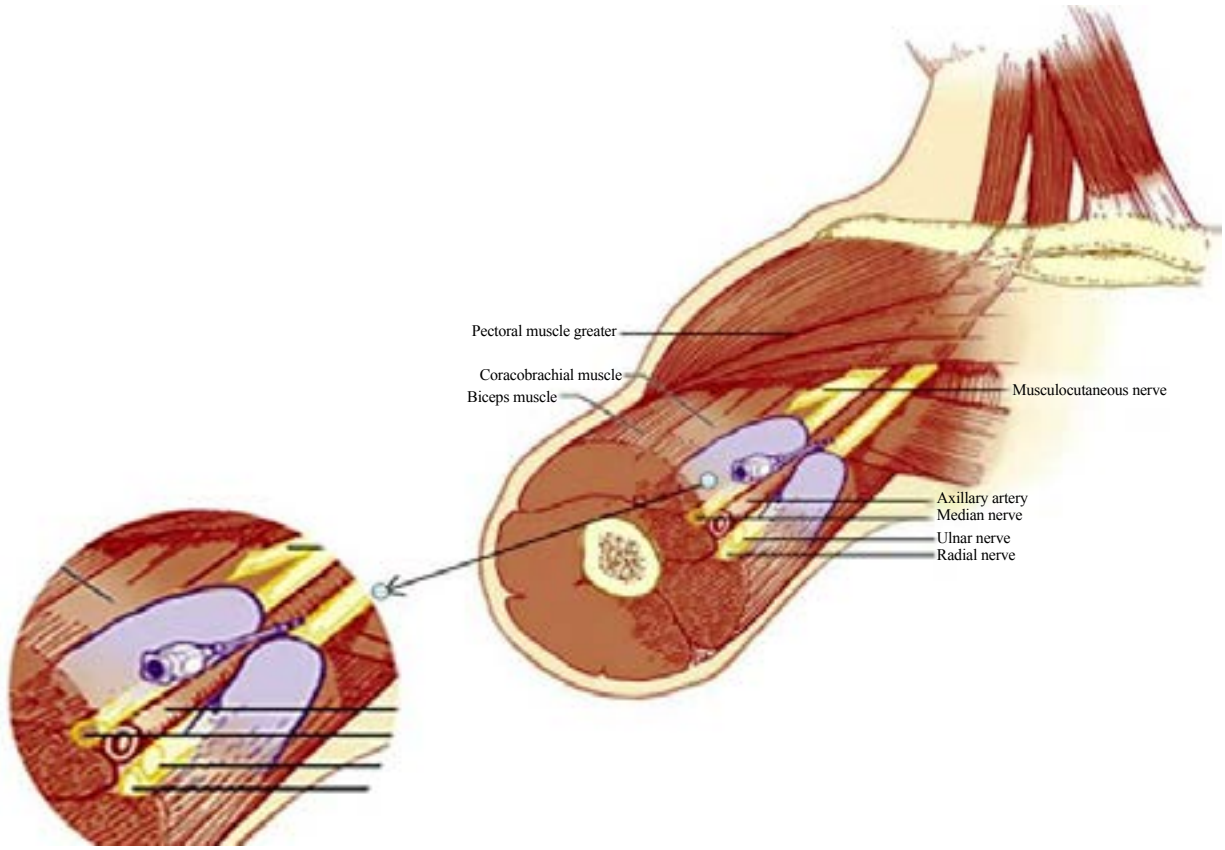

Figure 1. Anatomical region of mid humeral BP block method [91].

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

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 humorous. 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

The current research hasn't received any financial support.

Conflict of Interest

The authors of this study declared no conflict of interests.

References

[1] Gray H, Standring S. Gray's anatomy: the anatomical basis of clinical practice. 40th ed. Edinburgh: Churchill-Livingstone Elsevier; 2008, p. 822-28.

[2] Haviarova Z, Falougy H, Killingerova A, Matejcik V. Variation of the Median nerve course and its Clinical importance. Biomedical papers of the Medical Faculty of the University Palacký, Olomouc, Czechoslovakia. 2009; 153(4):303-06.

[3] Talhar S, Sontakke B, Bokariya P, Tarnekar A, Shende M. Bilateral variation in formation of median nerve. Journal of Pharmacy. 2012; 2(6):5-7.

[4] Itoo MS, Hussain RT, Itoo OB, Akhter F, Bhat GM, Shah BA, et al. Third root of median nerve-a cadaveric study. International Journal of Basic and Applied Sciences. 2014; 3(3):254-56.

[5] Shashanka M, Swaroop N, Girish V. An Anatomical Study on Variations in Relation to Musculaocutaneous and Median Nerve of Upper Limb. Global Journal of Medical Research. 2014; 14(1):21-24.

[6] Kumari KL, Rao MS, Ashalatha D, Elena GK, Sailaja L. Anatomical variation in the formation and course of median nerve: a cadaveric study. International Journal of Research in Medical Sciences. 2015; 3(6):1345-347.

[7] Bhanu PS, Sankar KD, Susan P. Formation of median nerve without the medial root of medial cord and associated variations of the brachial plexus. International Journal of Anatomical Variations. 2010; 3:27-29.

[8] Ghorai S. Formation of median nerve by three roots and origin of musculocutaneous nerve from lateral root of median nerve. International Journal of Current Research and Review. 2013; 5(23):55-58.

[9] Indrasingh I, Jacob TM, Pandurangan T, Padmavathy KM. A case of communicating rami between the median and musculocutaneous nerves passing through the substance of an accessory head of biceps brachii. Journal of Neurosciences in Rural Practice. 2014; 5(5):95-96.

[10] Maeda S, Kawai K, Koizumi M, Ide J, Tokiyoshi A, Mizuta H, et al. Morphological study, by teasing examination, of the communication from the musculocutaneous to median nerves. Anatomical Science International. 2009; 84(1-2):41-46.

[11] Oluyemi K, Adesanya O, Ofusori D, Okwuonu C, Ukwenya V, Om'iniabohs F, et al. Abnormal pattern of brachial plexus formation: an original case report. The Internet Journal of Neurosurgery. 2007; 4(2):1-7.

[12] Fazan VPS, Amadeu AS, Caleffi AL, Rodrigues Filho OA. Brachial plexus variations in its formation and main branches. Acta Cirurgica Brasileira. 2003; 18(5):14-18.

[13] Nene AR. Why are medial cord variations seen infrequently. European Journal of Anatomy. 2010; 14(2):59-65.

[14] Pais D, Casal D, Santos A, Goyri-O'Neill J. A variation in the origin of the median nerve associated with an unusual origin of the deep brachial artery. Journal of Morphological Sciences. 2010; 27(1):35-38.

[15] Das S, Paul S. Anomalous branching pattern of lateral cord of brachial plexus. Journal of Morphological Sciences. 2005; 23(4):289-92.

[16] Zhang Y, Yang S, Yang F, Xie P, Zhang Y, Yang S, et al. Absence of musculocutaneous nerve associated with variations of distribution patterns of the median nerve. International Journal of Morphology. 2014; 32(2):461-63.

[17] Aydin ME, Kale A, Edizer M, Kopuz C, Demir M, Corumlu U. Absence of the musculocutaneous nerve together with unusual innervation of the median nerve. Folia Morphologica. 2006; 65(3):228-31.

[18] Parchand MP, Patil ST. Absence of musculocutaneous nerve with variations in course and distribution of the median nerve. Anatomical Science International. 2013; 88(1):58-60.

[19] Suseelamma D, Krishna CK, Sharada H, Deepthi S. Radix formation between median and musculocutaneous nerves: embryological, morphological and clinical correlation. International Journal of Research in Medical Sciences. 2013; 1(3):222-25.

[20] Mahato NK. Entrapment of the median nerves and brachial arteries in the lower arm bilaterally and additional origin of biceps brachii muscle: Case report. International Journal of Morphology. 2010; 28(4):1241-244.

[21] Ongeti K, Pulei A, Ogeng'o J, Saidi H. Unusual formation of the median nerve associated with the third head of biceps brachii. Clinical Anatomy. 2012; 25(8):961-62.

[22] Sawant SP, Shaikh ST, More RM. Study of anastomosis between the musculocutaneous nerve and the median nerve. International Journal of Analytical, Pharmaceutical and Biomedical Sciences. 2012; 1(3):37-43.

[23] Yershov D, Hudák R. Unusual Variation of the Biceps Brachii with Possible Median Nerve Entrapment. Prague Medical Report. 2015; 116(2):167-72.

[24] Orebaugh SL, Williams BA. Brachial plexus anatomy: normal and variant. The Scientific World Journal. 2009; 9:300-12. doi: 10.1100/tsw.2009.39

[25] Abhaya A, Khanna J, Prakash R. Variation of the lateral cord of brachial plexus piercing coracobrachialis muscle. Journal of the Anatomical Society of India. 2003; 52(2):168-70.

[26] Sargon M, Uslu S, Celik H, Akşit D. A variation of the median nerve at the level of brachial plexus. Bulletin de l'Association des Anatomistes. 1995; 79(246):25-26.

[27] Kabak S, Ekinci N, Halici M, Karaoglu S, Unur E, Ulger H. Formation variations of median nerve. Joint Diseases and Related Surgery. 2001; 12:183-85.

[28] Saeed M, Rufai AA. Median and musculocutaneous nerves: variant formation and distribution. Clinical Anatomy. 2003; 16(5):453-57.

[29] Goyal N, Gupta M. Bilateral variant contributions in the formation of median nerve. Surgical and Radiologic Anatomy. 2005; 27(6):562-65.

[30] Jafari Anrkooli I, Mahmoudian A, Karimfar M. A rare bilateral variation in the formation of median nerve. Journal of Iranian Anatomical Sciences. 2007; 4(17):383-87.

[31] Aggarwal A, Harjeet K, Sahni D, Aggarwal A. Bilateral multiple complex variations in the formation and branching pattern of brachial plexus. Surgical and Radiologic Anatomy. 2009; 31(9):723-31.

[32] Satyanarayana N, Vishwakarma N, Kumar G, Guha R, Dattal A, Sunitha P. Rare variations in the formation of median nerve-embryological basis and clinical significance. Nepal Medical College Journal. 2009; 11(4):287-90.

[33] Sontakke BR, Tarnekar AM, Waghmare JE, Ingole IV. An unusual case of asymmetrical formation and distribution of median nerve. International Journal of Anatomical Variations. 2011;4:57-60.

[34] Budhiraja V, Rastogi R, Asthana A. Anatomical variations of median nerve formation: embryological and clinical correlation. Journal of Morphological Science. 2011; 28(4):283-86.

[35] Bhanu PS, Sankar KD. Bilateral absence of musculocutaneous nerve with unusual branching pattern of lateral cord and median nerve of brachial plexus. Anatomy & Cell Biology. 2012; 45(3):207-10.

[36] Rao BS, Leela V. Variant formation of median nerve–a review of Literature. International Journal of Pharma and Bio Sciences. 2013; 4(2):669-72.

[37] Nakatani T, Tanaka S, Mizukami S. Two rare anomalies of the brachial plexus. Journal of Anatomy. 1998; 192(2):303-04.

[38] Uzun A, Bilgic S. Some variations in the formation of the brachial plexus in infants. Turkish Journal of Medical Sciences. 1999; 29(5):573-78.

[39] Patil S, Meshram M, Kasote A, Kamdi N. Formation of median nerve from single root on left side and communicating branch from median nerve to musculocutaneous nerve on right side. Morphologie. 2012; 96(313):51-54.

[40] Uzun A, Seelig LL. A variation in the formation of the median nerve: communicating branch between the musculocutaneous and median nerves in man. Folia Morphologica. 2001; 60(2):99-101.

[41] Ramachandran K, Kanakasabapathy I, Holla S. Multiple variations involving all the terminal branches of the brachial plexus and the axillary artery-a case report. European Journal of Anatomy. 2007; 11(1):61-66.

[42] Choi D, Rodríguez-Niedenführ M, Vazquez T, Parkin I, Sañudo JR. Patterns of connections between the musculocutaneous and median nerves in the axilla and arm. Clinical Anatomy. 2002; 15(1):11-17.

[43] Chaudhary P, Singla R, Arora K, Kalsey G. Communicating ramus from lateral root of median nerve to ulnar nerve and fusion of musculocutaneous nerve & median nerve-a conjunction or co-incidence? International Journal of Anatomy and Research. 2013; 1(2):93-99.

[44] Kaus M, Wotowicz Z. Communicating branch between the musculocutaneous and median nerves in human. Folia Morphologica. 1995; 4(54):273-77.

[45] Basar R, Aldur M, Celik H, Yüksel M, Tascioglu A. A connecting branch between the musculocutaneous nerve and the median nerve. Morphologie. 2000; 84(266):25-27.

[46] Prasada Rao P, Chaudhary S. Absence of musculocutaneous nerve: two case reports. Clinical Anatomy. 2001; 14(1):31-35.

[47] Sarikcioglu L, Coskun N, Ozkan O. A case with multiple anomalies in the upper limb. Surgical and Radiologic Anatomy. 2001; 23(1):65-68.

[48] Badawoud M. A study on the anatomical variations of median nerve formation. Bahrain Medical Bulletin. 2003; 25(4):1-9.

[49] Beheiry EE. Anatomical variations of the median nerve distribution and communication in the arm. Folia morphologica. 2004; 63(3):313-18.

[50] Loukas M, Aqueelah H. Musculocutaneous and median nerve connections within, proximal and distal to the coracobrachialis muscle. Folia Morphologica. 2005; 64(2):101-08.

[51] Kocabiyik N, Yalcin B, Yazar F, Ozan H. An accessory branch of musculocutaneous nerve joining median nerve. Neuroanatomy. 2005; 4:13-15.

[52] Budhiraja V, Rastogi R, Asthana AK, Sinha P, Krishna A, Trivedi V. Concurrent variations of median and musculocutaneous nerves and their clinical correlation–a cadaveric study. Italian Journal of Anatomy and Embryology. 2011; 116(2):67-72.

[53] Agarwal S, Tuli A, Raheja S. Communication between median and musculocutaneous nerves in the forearm hooking around the origin of the median artery: a rare variation. Anatomical Science International. 2011; 86(3):175-77.

[54] Tomar V, Wadhwa S. Asymmetric bilateral variations in the musculocutaneous and median nerves with high branching of brachial artery. Acta Medica (Hradec Kralove). 2012; 55(4):189-92.

[55] El Falougy H, Selmeciova P, Kubikova E, Stenova J, Haviarova Z. The variable communicating branches between musculocutaneous and median nerves: a morphological study with clinical implications. International Journal Bratislava Medical Journal. 2013; 114(5):290-94.

[56] Kumar N, Guru A, D'Souza M, Patil J, Nayak B. Incidences and Clinical Implications of Communications between Musculocutaneous Nerve and Median Nerve in the Arm-A Cadaveric Study. West Indian Medical Journal. 2013; 62(8):744-47.

[57] Darji AP, Chauhan HM, Khatri H, Aterkar S, Pensi CA. Variations in branching pattern of Brachial Plexus: a cadaveric study. International Journal of Biomedical and Advance Research. 2013; 4(3):174-78.

[58] Radunovic M, Vukasanovic-Bozaric A, Radojevic N, Vukadinovic T. A new anatomical variation of the musculocutaneous and the median nerve anastomosis. Folia Morphologica. 2013; 72(2):176-79.

[59] Iwamoto S, Kimura K, Takahashi Y, Konishi M. Some aspects of the communicating branch between the musculocutaneous and median nerves in man. Okajimas Folia Anatomica Japonica. 1990; 67(1):47-52.

[60] Chauhan R, Roy T. Communication between the median and musculocutaneous nerve–a case report. Journal of the Anatomical Society of India. 2002; 51(1):72-75.

[61] Arora J, Kapur V, Suri R, Khan R. Inter-communications between median and musculocutaneous nerves with dual innervation of brachialis muscle-a case report. Journal of the Anatomical Society of India. 2003; 52(1):66-68.

[62] Nakatani T, Mizukami S, Tanaka S. Three cases of the musculocutaneous nerve not perforating the coracobrachialis muscle. Journal of Anatomy. 1997; 72(3):191-94.

[63] Aggarwal N, Kaur N, Kaur J, Gupta M. Fusion of main trunks of median and musculocutaneous nerves (an anatomic variation). National Journal of Integrated Research in Medicine. 2013; 4(1):154-58.

[64] Nayak S, Samuel VP, Somayaji N. Concurrent variations of median nerve, musculocutaneous nerve and biceps brachii muscle. Neuroanatomy. 2006; 5:30-32.

[65] Nayak S. Absence of musculocutaneous nerve associated with clinically important variations in the formation, course and distribution of the median nerve: a case report. Neuroanatomy. 2007; 6:49-50.

[66] Satyanarayana N, Vishwakarma N, Kumar G, Guha R, Datta A, Sunitha P. Variation in relation of cords of brachial plexus and their branches with axillary and brachial arteries: a case report. Nepal Medical College Journal. 2009; 11(1):69-72.

[67] Pandey S, Shukla V. Anatomical variations of the cords of brachial plexus and the median nerve. Clinical Anatomy. 2007; 20(2):150-56.

[68] Haviarova Z, El Falougy H, Killingerova A. Atypical course of the median nerve. International Journal Bratislava Medical Journal. 2001; 102(8):372-73.

[69] Nene AR, Gajendra KS, Sarma MVR. Variant formation and course of the median nerve. International Journal of Anatomical Variations. 2010; 3:93-94.

[70] Ihunwo A, Osinde S, Mukhtar A. Distribution of median nerve to muscles of the anterior compartment of the arm. Central African Journal of Medicine. 1997; 43(12):359-60.

[71] Sud M, Sharma A. Absence of musculocutaneous nerve and the innervation of coracobrachialis, biceps brachii and brachialis from the median nerve. Journal of the Anatomical Society of India. 2000; 49(2):176-77.

[72] Gümüsburun E, Adigüzel E. A variation of the brachial plexus characterized by the absence of the musculocutaneous nerve a case report. Surgical and Radiologic Anatomy. 2000; 22(1):63-65.

[73] Pacholczak R, Klimek-Piotrowska W, Walocha JA. Absence of the musculocutaneous nerve associated with a supernumerary head of biceps brachii: a case report. Surgical and Radiologic Anatomy. 2011; 33(6):551-54.

[74] Sushma R, Radhakrishnan P, Divya Shenoy KM. Multiple Anatomical Variations in the Arm in an Indian Case. Anatomy Journal of Africa. 2013; 2(2):117-18.

[75] Tatar I, Brohi R, Sen F, Tonak A, Celik H. Innervation of the coracobrachialis muscle by a branch from the lateral root of the median nerve. Folia Morphologica. 2004; 63(4):503-06.

[76] Gümüşalan Y, Ozan H. Variant innervation of the coracobrachialis muscle and unusual course of the musculocutaneous nerve in man. Journal of Anatomy. 1998; 73(3):269-72.

[77] Kazuki K, Egi T, Okada M, Takaoka K. Anatomic variation—a bony canal for the median nerve at the distal humerus: a case report. Journal of Hand Surgery. 2004; 29(5):953-56.

[78] Bilecenoglu B, Uz A, Karalezli N. Possible anatomic structures causing entrapment neuropathies of the median nerve: an anatomic study. Acta Orthopædica Belgica. 2005; 71(2):169-76.

[79] Saralaya V, Nayak R, Sequeira S, Madhyastha S, Krishnamurthy A, D'Costa S. An unusual tunnel formation in the arm and its clinical significance. International Journal of Anatomical Variations. 2009; 2:27-28.

[80] Sawant S. The neurovascular compression due to the third head of biceps brachii in the right arm: a case report. World Research Journal of Anatomy. 2013; 1:4-6.

[81] Gunther SF, Dipasquale D, Martin R. Struthers' ligament and associated median nerve variations in a cadaveric specimen. Yale Journal of Biology and Medicine. 1993; 66(3):203-208.

[82] Wadhwa S, Mehra S, Khan R, Kapur V. Abnormal musculoaponeurotic tunnel in the arm. Clinical Anatomy. 2004; 17(4):360-63.

[83] Rodrigues V, Nayak S, Nagabhooshana S, Vollala VR. Median nerve and brachial artery entrapment in the tendinous arch of coracobrachialis muscle. International Journal of Acoustics and Vibration. 2008; 1:28-29.

[84] Martin R. Tal om nervers allmänna egenskaper i människans kropp. Stockholm: Lars Salvius; 1763.

[85] Gruber W. Uber die Verbindung des Nervus medianus mit dem Nervus ulnaris am Unterarme des Menschen und der Saugethiere. Archive of Journal of Anatomy and Physiology. 1870; 37:501-22.

[86] Walsh J. The Anatomy of the Brachial Plexus. American Journal of the Medical Sciences. 1877; 74(148):387-99.

[87] Venieratos D, Anagnostopoulou S. Classification of communications between the musculocutaneous and median nerves. Clinical Anatomy. 1998; 11(5):327-31.

[88] Le Minor J. A rare variation of the median and musculocutaneous nerves in man. Archives d'Anatomie, d'Histologie et d'Embryologie Normales et Experimentales. 1989; 73:33-42.

[89] Sontakke YA, Fulzele R, Tamgire D, Joshi M, Gajbe UL, Marathe RR. Unilateral variant origin of musculocutaneous nerve. International Journal of Anatomical Variations. 2010; 3:59-60.

[90] Fuss F. The lateral root of the ulnar nerve. Acta Anatomica. 1988; 134(3):199-205.

[91] Horlocker TT, Kopp SL, Wedel DJ. Peripheral Nerve Blocks. In: Miller RD, editor. Miller's Anesthesia. 8th ed. Philadelphia: Elsevier Saunders; 2015. p. 1730-740.

[92] Bergman R, Thompson S, Afifi A, Saadeh F. Compendium of human anatomic variation. Baltimore: Urban and Schwarzenberg; 1988.

[93] Brown MC, Hopkins WG, Keynes RJ. This variation in the median nerve. 1st ed. Cambridge: Cambridge University Press; 1991.

[94] Collins P. Embryology and development. In: Williams P, Bannister L, Berry M, editors. Gray's Anatomy. In: Embryology and development. 38th ed. New York: Churchill-Livingstone; 1999. p. 231-32.

[95] Matejcik V. Variations of nerve roots of the brachial plexus. International Journal Bratislava Medical Journal. 2005; 106(1):34-36.