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REVISITED ANATOMY OF ADDITIONAL HEADS OF BICEPS BRACHII MUSCLE AND COEXISTING MUSCULOCUTANEOUS NERVE VARIANTS

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ABSTRACT

Introduction: Incidence of additional heads of biceps brachii varies in different populations and its existence may influence the course of musculocutaneous nerve leading to variations. This study was proposed to observe this additional muscle and the associated nerve variations, in the Indian population.

Material & methods: Hundred upper limbs from 50 formalin embalmed cadavers were dissected.

Results: The additional heads were found in 10 cadavers (20%). Biceps brachii muscle with three heads was seen in 12 limbs and with four heads was seen in one. In 13 limbs with additional muscle, nine (69.2%) were from left side. Concurrent musculocutaneous nerve variations were present in five limbs (38.5%).

Conclusion: Presence of additional head in biceps brachii is not uncommon in the Indian population, and is mostly seen on the left side. Presence of extra head is likely to simulate the soft tissue tumors and muscle tears, and should be considered during the analysis of the diagnostic scans.

KEYWORD

Morphology, Musculocutaneous nerve, Upper extremity, Incidence, Musculoskeletal Abnormalities.

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Introduction

Biceps brachii (BB) is a muscle of the front of arm. The long and short heads of BB arise from the supraglenoid tubercle and the coracoid process, respectively. Two heads form a tendon near the elbow for insertion into the radial tuberosity. (1) When another muscle mass joins it before insertion, it is termed as an extra, supernumerary, additional or accessory head of BB. (1-6) The third head in BB is encountered more often than the fourth or higher number of heads, however its incidence is variable. The accessory muscle usually attaches to the medial side of humerus near coracobrachialis (CB) or brachialis, and distally fuses with the inner aspect of the biceps brachii tendon. (1-3) It is seen as a thick muscle in most of the cases and may present as a soft tissue mass in arm especially if bulky. (7) Moreover, an extra head is likely to simulate a muscle tear in the diagnostic image of the upper limb. (5)

Variable incidence of the additional head of biceps muscle (AHB) is described in the literature from the multiple ethnic populations such as, 8% in Chinese, 10% in white Europeans, 12% in black Africans, and 18% in Japanese. (3) In comparison, the prevalence is reported to be low in the Indian population. [(4,8-10)]

BB acts as a flexor at the elbow, and its principle action is supination. (1) The presence of an additional head adds to the muscle mass. This is likely to affect the biomechanics of BB (11), and has the potential to create imbalance at the elbow due to extra muscle bulk in the flexor aspect of the brachium.

Musculocutaneous nerve (MCN) is one of the branches of the lateral cord of brachial plexus. It supplies BB and the other muscles of the anterior compartment of arm, before giving the lateral cutaneous nerve of forearm. After passing through CB, MCN runs beneath BB in the arm. A communicating branch (COB) is seen if few median nerve (MN) fibers enter MCN and later leave it to join MN, though rarely fibers travel in the reverse direction. (1) The incidence of absent MCN is 3.6%, and that of the nerve connections between MCN and MN is 53.6%. (12) Venieratos and Anagnostopoulou observed such COB in 13.9%. (13)

It has been suggested that AHB influences the course of MCN leading to the nerve variants, and can impinge on it especially if the nerve is running in a close relation to it. (8, 14) In studies on the AHB, variations in MCN, like the absence of MCN, duplication of MCN, altered course of MCN, or COB between MN and MCN have been reported. (4, 7, 15, 16) The incidence of COB tends to be higher in the presence of AHB. (16) According to Techataweewan et al., Ballesteros et al. and Kosugi et al., COB concurrent with AHB are seen in 9.3%, 23.8% and 54.7%, respectively. (4, 7, 16) However, there is scarcity of literature on the incidence of MCN variations associated with AHB in the Indian population. Also, the existing knowledge on the morphology of AHB in Indians is limited. This study intended to find out the incidence of AHB in the cadavers from the Indian population, and describe its attachments, morphology, relations, and the simultaneous presence of MCN variants.

Material and methods

Fifty adult formalin-embalmed cadavers (42 male, eight female), with an average age of 61 years (range 52-70), available in department of Anatomy from 2014-2018 were selected for this study. The upper limbs with any apparent deformity, damage, or signs of surgery were excluded. The cadavers were obtained through institutional body donation program following ethical guidelines and all the specimens were stored in 10% formalin solution after embalming.

For gross dissection, a vertical incision was placed in the skin of the front of the arm and the elbow. The line of incision extended from the acromion process to the radial tuberosity, and was joined by horizontal incisions at the two ends. The skin flaps were reflected and the underlying subcutaneous tissue and deep fascia were cleared. The muscles of the anterior compartment of arm were exposed by the blunt dissection and subsequently examined for the presence of any AHB. The number, laterality, attachments, morphology, length, and nerve supply of the extra heads were recorded. The length of AHB was measured from origin till its fusion with the biceps muscle. In the limbs with an additional head, any MCN variation if present was noted. Two independent observers, both anatomists, recorded the findings. All measurements were taken using a Vernier Caliper with a sensitivity of 0.01mm and the mean of three readings was taken as final.

Results

AHB was seen in 20% cadavers (10 out of 50). The three-headed BB was bilateral in three and unilateral in five male cadavers (left: four, right: one), and unilateral (left) in one female cadaver. The four-headed muscle was present on the left arm in one male cadaver.

In 100 upper limbs (males- 84, females- 16), BB with two heads was observed in 87 limbs, three heads in 12 and four heads in one. So, a total of 14 extra heads were present in 13 limbs. The distribution as per the number of heads in BB is shown in Table 1. The incidence of AHB was 14.2% (12 out of 84) in the males and 6.3% (one out of 16) in the females. Among the 13 limbs, AHB was left sided in nine (69.2%) and right-sided in four (30.8%).

Table 1: Incidence of additional heads of biceps brachii.

Number of heads in biceps brachii	Male		Female	
	Right N=42	Left N=42	Right N=8	Left N=8
Two heads	38 (90.5)	34 (80.9)	8 (100)	7 (87.5)
Three heads	4 (9.5)	7 (16.7)	0	1 (12.5)
Four heads	0	1 (2.4)	0	0

No variation was observed in the attachments of long and short heads of BB. AHB was located deep to the main belly of biceps and joined either with the belly or tendon. Ten muscles (71.4%) joined with tendon and four (28.6%) with the belly of BB. The fusion with the tendon was left-sided in 70% (seven out of 10), and that with the belly was left-sided in 75% (three out of four). The extra head joining BB tendon, fused with it on the inferomedial aspect and contributed greatest to the bicipital aponeurosis. Twelve accessory muscles (85.7%) merged with BB in lower part of arm near the elbow and two (14.3%) in the middle of arm.

All the 14 additional heads were humeral in origin. The origin was fleshy and vertically positioned in 13 (92.9%) and tendinous and transversely placed in one (7.1%) as shown in Fig 1B. The most common site of origin was on the medial side of shaft of humerus, where it was either between CB insertion and brachialis origin (anterolateral), or medial to CB insertion (posteromedial). The posteromedial origin in one muscle extended to the medial intermuscular septum and fascia over brachialis. This muscle covered the median nerve and brachial artery such that these structures passed under a musculofascial tunnel in the lower half of arm (Fig 1C). A high origin was noted in two cases, one was on the anterior aspect of humerus shaft just above brachialis attachment, and the other was on the medial margin of shaft between insertions of teres major and CB. All the anteromedial attachments were right-sided, and those with high origin were on the left side. The anterolateral origin was left sided in 87.5% (seven out of eight). Overall, three types of origin were noted: anterolateral in eight (57.1%), posteromedial in four (28.6%), and high origin in two (14.3%).

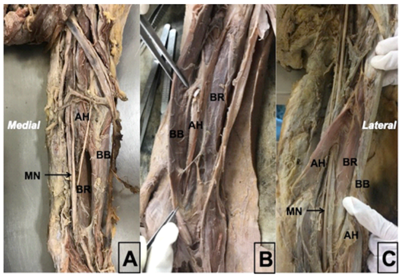

Fig 1: A- Left upper limb with short and broad AH. B- Left upper limb showing long, thin and narrow AH with tendinous origin. C- Left upper limb with MN and brachial artery passing under AH. AH: additional head; BB: biceps brachii; BR: brachialis; MN: median nerve.

Three types of AHB morphology were encountered: Type I- long, thin and narrow (Fig 1B); Type II- long thick and broad; Type III- short, thick and broad (Fig 1A). Type I appeared in five (35.7%), type II in seven (50%), and type III in two (14.3%). All type I cases and 57.1% (four out of seven) of type II were left sided, whereas type III was equally distributed on the two sides.

The length of AHB varied from 4.7 to 18.1 cm, the average being 11.6 ± 4.0 cm. Table 2 shows the average length of AHB in the two sexes.

Table 2: Length (cm) of additional head of biceps brachii.

Male		Female		Right	Left
Right	Left	Right	Left		
9.8 ± 3.3	12.2 ± 4.4	-	13.6 ± 0.14	9.8 ± 3.3	12.3± 4.1 cm

MCN supplied the AHB in 12 limbs, and in one case where MCN was absent, a branch from the lateral cord supplied it (Fig 1E). An added innervation from MN was observed in three (23.1%). MCN was located between BB and AHB in one limb (right side), and between AHB and brachialis in 12. The incidence of MCN variations are specified in Table 3.

Table 3: Incidence of musculocutaneous nerve (MCN) variations associated with additional head of biceps brachii.

	Type of MCN Variation	Incidence (%) N=13
1.	No MCN variation	8(61.5)
2.	Absence of MCN	1(7.7)
3.	One communicating branch between MCN and median nerve	3(23.1)
4.	Two communicating branches between MCN and median nerve	1(7.7)

The concurrent AHB and MCN variations were seen ipsilaterally in five limbs (38.5%), four male and one female. All the nerve variants in the presence of AHB were unilateral, in which 60% were left-sided (three out of five). Out of four COB, three were directed from MCN to MN, and one from MN to MCN (Fig 2B). The case from a female cadaver was left-sided with two COB (Fig 2D). The relation of COB to CB and AHB was variable. The two COB in proximal third of arm were given off from MCN, before its entry into CB (Fig 2A) and during its passage through CB (Fig 2D). The three distal COB were seen between AHB and BB (Fig 2B), between AHB and brachialis (Fig 2C), and medial to AHB (Fig 2D).

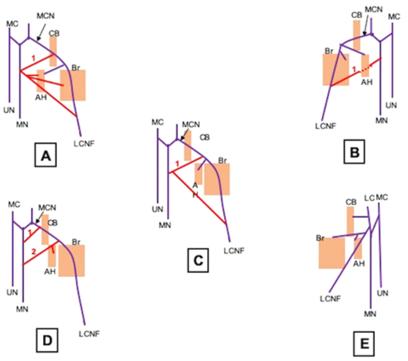

Fig 2: Variations in MCN. A: (left) one communicating branch (COB) from MCN to MN. Branches to AH and Br arise where COB joined MN. B: (right) one COB passing between AH and Br. C: (left) one COB passing between CB and upper margin of AH. D: (left) two COBs, first arises from MCN before it enters CB. Second COB supplied AH. E: (right) MCN absent and all the muscles are supplied by lateral cord. MCN: musculocutaneous nerve; CB: coracobrachialis; AH: accessory head; Br: brachialis; MN: median nerve; LCNF: lateral cutaneous nerve of forearm; LC: lateral cord; UN: ulnar nerve; BB: branch to biceps brachii; 1, 2: communicating branches between median and musculocutaneous nerves.

Discussion

The variable incidence of the AHB in the different populations is well documented (Table 4). Ethnic differences in are presumed to be due to the morphological adaptations in the BB. (7, 17, 18) The incidence is high in the Thai and Colombian than in the South Asian population from India and Sri Lanka. (4, 17)

Table 4: Incidence of additional head of biceps brachii in various populations.

S.NO.	STUDY	Year	Number of cadavers	POPULATION	INCIDENCE (%)
1.	Kosugi	1992	273	Japanese	21.2
2.	Asvat	1993	85	South Africa	20.5 (Blacks) 8.3 (Whites)
3.	Neto	1998	100	Brazil	Whites-20 Blacks- 9
4.	Rodriguez	2003	175	Spain	15.4
5.	Nayak	2006	48	India	2.08
6.	Rai	2007	42	India	7.1
7.	Kumar	2008	48	India	3.33
8.	Cheema	2011	63	India	2.3
9.	Ilayperuma	2011	135	Sri Lanka	3.7
10.	Pakhale	2012	40	India	3.75
11.	Nasr	2013	50	Saudi Arabia	10
12.	Ballesteros	2014	53	Columbia	19.8
13.	Da Silva	2016	74	Brazil	13.5
14.	Techataweewan	2016	162	Thailand	35
15.	Present study	2019	50	India	20

Compared to other studies from India (Table 4), our study revealed a higher incidence of AHB. In study by Asvat et al., extra head was more common in the black compared to the whites, and in a study by Neto et al., extra head was more frequent in white. (11, 19) The comparison of the two studies mentioned above reflects that the high incidence of extra head may not always be related to the race. AHB is mostly identified as humeral in origin, and the medial side of shaft near CB is the most frequent site of attachment. (3, 4, 6, 9, 11, 16-23) This is similar to the findings in the present study and we found the area close to CB insertion to be prevalent in 85.7% (12 out of 14). The other sites of AHB attachment can be pectoralis major, (3, 16, 19, 20, 24) shoulder joint capsule, (3, 6, 16) lesser tubercle, (20) greater tubercle, (5, 16) deltoid tuberosity, (8) bicipital groove margins, and medial intermuscular septum. (16) Accessory fibers can also come from brachialis, long and short heads of BB, CB, coracoid process. (4, 6) Origin from the deltoid fascia or insertion is rare. (11) The origin near deltoid tuberosity, CB and pectoralis major insertion is seen in 8%, 6% and 4%, respectively. (3) The surgical approach to shoulder can be affected if accessory muscle attaches close to the upper part of the humerus. (14)

Though AHB mostly takes a fleshy origin, a tendinous one is sometimes seen. (5) There was only one such case in the present study. Rincon et al., have classified the origin as superior, inferomedial, and inferolateral. (17) The inferomedial type or origin from the medial side of humerus shaft is the most common. (17, 25) We identified anterolateral, posteromedial and high origin on the basis of its relation to CB insertion, and AHB was mostly anterolateral type at the origin. The knowledge of muscle origin is relevant to interpret cases with suspected soft tissue injury to differentiate traumatic muscle split from the other causes.

Kosugi et al. classified the insertion into four types according to the fusion of AHB to the belly, tendon, short head, and long head. (16) The insertion to the belly was found to be the most common. This is similar to the study by Nasr and Hussein. (6) However, according to Rincon et al., the muscle rarely joins the biceps belly. (17) As per our observation, the extra head mostly fused with the tendon. This is supported by reports from several other authors. (4, 7, 10, 11, 17, 20, 26) These variations in insertion are believed to be due to factors affecting the muscle development. (6)

Similar to our report, other studies have described AHB as a male dominated condition. (4, 9-11, 17, 18, 20, 27) It is more prevalent in the female cadavers from Japan (16) and North America, (22) and Techataweewan et al. have reported equal incidence in both the sexes. (4)

Additional head is usually unilateral in presentation. [4, 9, 18, 20, 25] Since most people are right-handed, it is mainly believed to be a right-sided condition. (7, 15, 17, 21, 25, 27, 28) Some studies have identified it to be more common on the left. (4, 6, 9, 11, 20) Unilateral cases are common on the right side in males and on the left side in females. (16) In Thai, unilateral cases are common on left side in both sexes. (4) A unilateral case could present as an asymmetric lump in the upper limb and should be kept in mind to arrive at the appropriate diagnosis. (26) Bilateral cases are usually more common in males [11, 16] but equal in both sexes in Thai population. (4) We observed that both the bilateral and unilateral cases were more common in the males, and unilateral cases were more frequent on the left. Here, the third head was present in majority of cases with AHB, which concurs with many earlier studies. (3, 4, 6, 7, 9, 11, 17-19, 25, 27) More than four heads in BB did not appear in our sample.

The morphology of extra head is variable. It is usually well developed in the males where it is thicker on the left side and longer on the right side, whereas, we observed it to be longer on the left side in the male cadavers. In females, it is considered to be thin, and also longer on the left but thicker on the right. (4, 16, 21) Average length of an additional head is 11.8 cm (6, 7) which is comparable to our observation. Cheema and Singla found it be the 12.9 cm in sample from north India that was similar to the findings in Sri Lankan and Colombian populations, but was noticeably longer than our reading from south Indian population. (9, 17, 18) The specific influence of AHB on joint movements will depend on attachments. Muscle fibers from the humerus will act only on the elbow joint and medial origin on the shaft would work in the favor of pronation unlike the long and short heads. (11) The overall muscle power will be enhanced at the insertion site where AHB joins with the main BB tendon. This is likely to reflect in the movements of flexion at the elbow and supination. (8, 29)

Additional head is related superficially to BB and MCN. (7, 17) MCN passing beneath a large accessory muscle is vulnerable to compression [18]. Though extra head is innocuous in the majority, it becomes clinically apparent in instances of accessory head arching over the neurovascular structures in the arm, where compressive symptoms can appear. (8, 14, 30) We observed one case of accessory muscle covering median nerve and brachial artery, similar to the case reported by Nakatani et al. (31)

Communication between MN & MCN is more common in males. (16) Such cases are clinically significant in the cases of nerve entrapment and also place the nerve at risk during surgical procedures in the arm. The connecting branches should be carefully pursued and approached to avoid complications related to loss of nerve fibers. (13, 31) We observed communicating branches in 30.8% cadavers with AHB, all unilateral and ipsilateral. As per Choi et al. classification, three cases (Fig 2 A, B, C) were similar to pattern 2a and one case (Fig 2 D) was like pattern 3, but we observed most COBs on left. (32)

Cases shown in Figs 2B and C in our study were type II, and case 2D had both types I and II variations as per Venieratos and Anagnostopoulou, whereas, according to the classification proposed by Guerri-Guttenberg and Ingolotti, cases in figures 2B and 2C are similar to type I-A-1-D, and case 2D is comparable to type I-A-2-PD. Case 2A, however, did not fit these two classifications. Also, the simultaneous presence of an additional head of BB was not noticed in any these studies. (12, 13)

The accessory head is supplied by MN if MCN is absent. (3, 12, 27) It has also been proposed that presence of MCN variation influences the development of extra head. (3)

During muscle development in the fetal life, myotome of each somite forms epimere and hypomere. At the location of limb buds, myogenic cells from hypomeres move into the limbs in the fifth week of the intrauterine life. The ventral mass derived from these myoblasts forms muscles of the anterior compartment of the arm including BB. (33) The definitive structure of muscles depends on various factors like the segmentation of muscle mass, effect of T-box factors, and apoptosis during morphogenesis. (34) A disturbance in these factors could lead to the formation of accessory muscles. As spinal nerves grow into the limb buds, muscle cell surface molecules direct the growth and distribution of axons. (33) This provides a likely explanation for variation in the nerve course and branching seen with the accessory muscle heads.
In conclusion, based on the present study, AHB is more likely to be seen in males as a left-sided condition. AHB can be associated with nerve communications, which would possibly complicate surgical procedures in arm. Awareness of these variations is also important for the interpretation of radiological scans.

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