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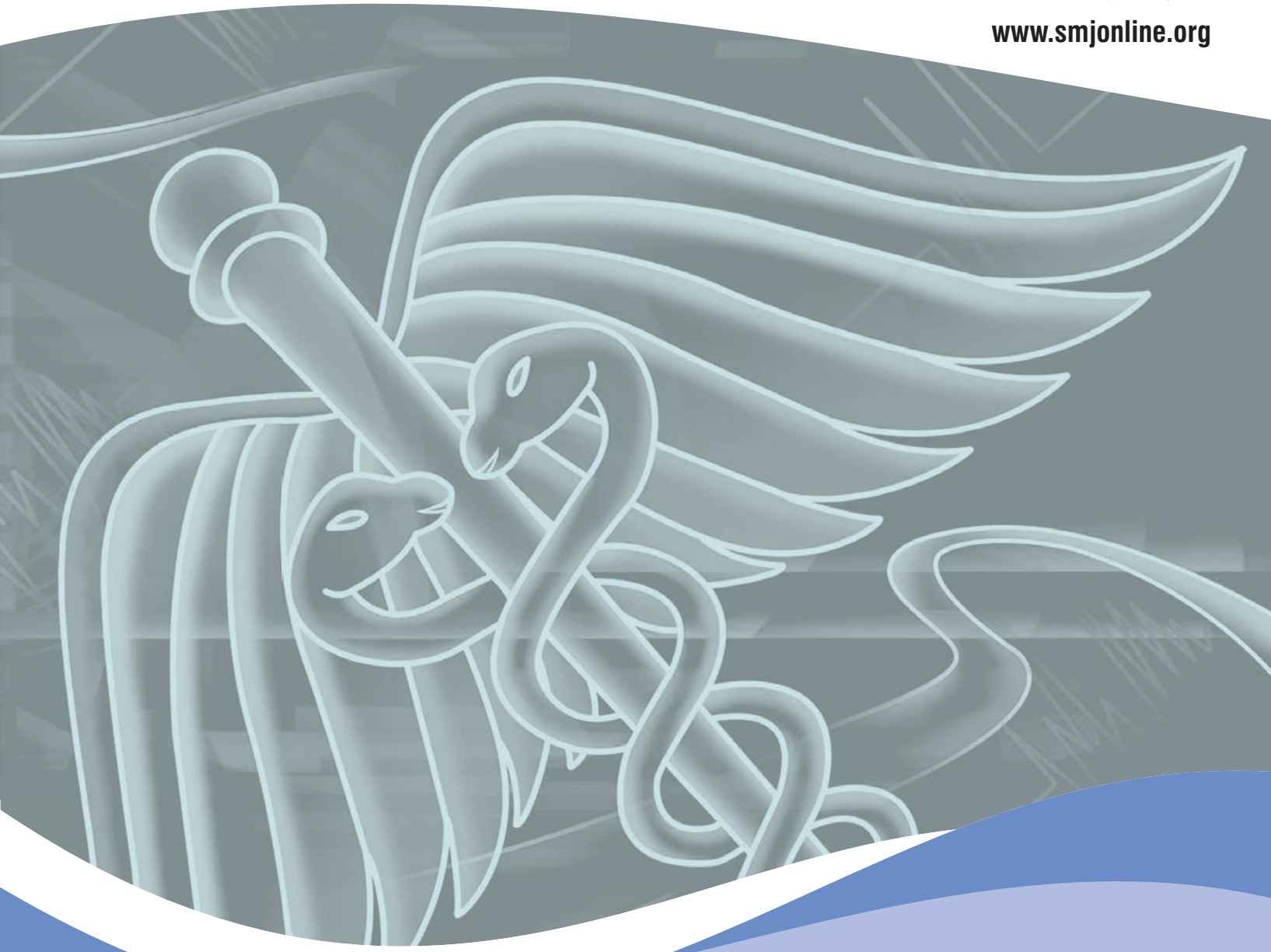

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ORIGINAL ARTICLE

A study of biceps brachii muscle: Anatomical considerations and clinical implications

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ABSTRACT

Context: Biceps brachii muscle (BBm) is a very variable muscle, the variations being associated with a variety of clinical conditions. This study delves on anatomical variations in this muscle, possible phylogenic causes for their frequency and their clinical importance. **Aims:** The aim was to study anatomy of bicep brachii muscle, its variations and their clinical importance. **Subjects and Methods:** A total of 60 upper limbs preserved in 10% formalin were dissected meticulously to study anatomical details of the BBm. **Results:** The incidence of variation in anatomy of BBm was 15%, with incidence being 11.6% and 3.3% among male and female cadavers studied, respectively. Variation was unilateral in 10% and bilateral in 3.3%. The incidence of third head was 13.3% out of which 3.3% took origin from the capsule of the shoulder joint, 8.3% from humerus, and 1.6% from brachialis muscle. Incidence of extra bellies of insertion was found to be 1.6%. A 3.3% incidence was observed in the nerve supply. **Conclusions:** Variations in BBm are a reflection of its late development in human phylum. The extra bellies can cause neurovascular compression, change the kinematics at the elbow joint and be misinterpreted as tears of muscle on magnetic resonance imaging. They should be watched for in the shoulder as well as elbow joint surgeries. The authors suggest that the extra bellies of BBm instead of being labeled as third, fourth or fifth heads, can be classified as those of origin and insertion and bellies of origin be referred to clearly as capsular, humeral or brachial heads.

Keywords: Anatomy, biceps brachii, biceps brachii in gibbons, extra head, musculocutaneous nerve, third head

INTRODUCTION

Biceps brachii (BBm) is a muscle belonging to the flexor compartment of the arm. It has been described as one of the muscles with most frequent anatomic variations.[1,2] About one to five heads of BBm have been reported previously in the literature.[2] The knowledge of such additional heads and associated variations in the architecture of the surrounding region is important because they can produce clinical symptoms by compressing surrounding neurovascular bundles.[3] This knowledge is also important for correct identification during imaging and to prevent iatrogenic injuries during surgery.[4,5] The presence of the additional head of BBm can also affect the kinematics of the joints the muscle acts on.[6]

This study was taken up to evaluate the BBm as regards its origins, insertion, nerve and blood supply, and variations if any. The relations of the variant muscles were studied in detail to analyze the possibility of a neurovascular bundle compression.

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SUBJECTS AND METHODS

A total of 60 upper limbs (ULs) (52 male, 8 female) of 30 formalin fixed cadavers were used in this study. These limbs were obtained from the dissection room of the Department of Anatomy of our Medical College. Dissection of these limbs was carried out over a period of 6 months.

The ULs of the cadavers were dissected by taking a longitudinal incision on the anterior aspect of arm, from the acromion process to a point 3 cm below the elbow joint. Horizontal incisions were made at the proximal and distal ends of the longitudinal incision bilaterally.

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After removal of skin, subcutaneous fat and fascia, the muscles of the arm were exposed, from origin to insertion. The blood vessels and nerves of this region were also dissected meticulously. Wherever necessary the incisions were extended proximally and distally for studying the details of the variations observed.

After meticulous dissection, the BBm was observed for the following:

1. Number of additional heads
2. Origin/proximal attachment (PA) and insertion/distal attachment (DA) of each head
3. Innervation and blood supply of each head.

Any associated variations were noted.

Appropriate photographs were taken.

RESULTS

The observations were noted in a tabular form [Table 1].

The type of variations observed in the anatomy of BBm is depicted in Table 2.

The extra heads of origin/PA of BBm were observed to be taking origin from one of the following sites.

1. Capsule of the shoulder joint
2. Anterior surface of humerus
3. Anterior surface of brachialis muscle.

Two ULs (3.3%) showed the extra head taking origin from the capsule of the shoulder joint. Both the limbs were of the right side and belonged to male cadavers. While in one limb, the extra head of origin could be clearly visualized as a separate belly attached to the capsule of the shoulder joint, in the other limb, the capsular head blended medially with the short head of biceps such that, the demarcation between the two heads was almost imperceptible [Figure 1a and b].

Five ULs (8.3%) showed the extra belly taking origin from the anterior surface of humerus just above the origin of brachialis muscle [Figure 2]. The variation was unilateral in 3 male cadavers and bilateral in one female cadaver. In all cases, the extra belly joined the other two heads of BBm just proximal to the elbow joint.

One UL (1.6%) showed origin of the extra head from the anterior surface of proximal 1/5th of brachialis muscle, uniting with the other two heads at the elbow joint [Figure 3].

In all the BBms studied, the long and short heads were seen joining proximal to the elbow joint, forming a flattened tendon, which got attached to the posterior part of radial tuberosity.

In one UL (1.6%), besides the normal tendon of insertion as described above, three extra bellies of insertion/DA were observed [Figure 4]. All were proximally attached to the medial border of short head of BBm. They were labeled as medial, intermediate and lateral according to their relative positions in the arm. The medial most belly was small and distally attached to the fascia covering brachialis muscle, while the intermediate belly was larger with a well-defined fusiform muscular form which

Table 1: Incidence of variation in anatomy of BBm observed in the present study

ULs for studying of BBm	Number of ULs	Male %	Female %
Total number of ULs studied	60	52	8
Number of ULs showing variation in anatomy of BBm	8	6	2
Percentage of incidence of variation in anatomy of BBm	15	11.6	3.3

BBm: Biceps brachii muscle; ULs: Upper limbs

Table 2: Type of variations seen in anatomy of BBm along with percentage of incidence of variation observed

The type of variation observed	Percentage of incidence of variation
Extra head of origin/PA of BBm	13.3
Extra belly of insertion/DA	1.6
Expansions from tendon of insertion/DA of extra belly	3.3
Communicating branch between MCN and MN	3.3
Innervation of BBm by branches from MN	1.6

BBm: Biceps brachii muscle; PA: Proximal attachment; DA: Distal attachment; MCN: Musculocutaneous nerve; MN: Median nerve

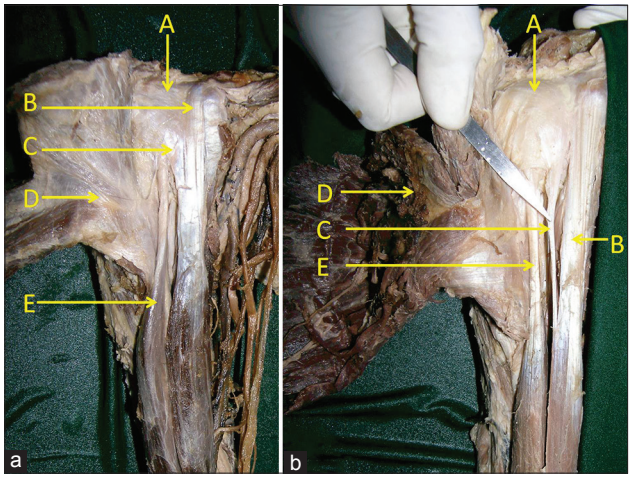

Figure 1: Photographs showing extra heads of biceps brachii muscle (BBm) (C) taking origin from the capsule of the shoulder joint (A). (a) The capsular head (C) is seen blending medially with the short head of BBm (B) and (b) the extra head of origin (C) is clearly visualized as a separate head. Also seen are the muscles pectoralis major (D) and long head of BBm (E)

later tapered into a thin long tendon that wound around the medial border of brachialis muscle before passing deep to it. Further distally it split into two slips, one part of which passed laterally to get attached to the radial tuberosity while the rest of it got attached to the coronoid process of ulna [Figure 5]. The lateral belly passed superficial to the brachialis tendon to split into several fibrous strands which spread out in the space between the radius and ulna, forming a mesh of fibrous strands that were attached to both radius and ulna, through which passed the branches of the median nerve (MN) and ulnar artery [Figure 6]. None of the extra tendons crossed the brachial artery or the main trunk of MN.

Two ULs (3.3%) showed expansions from tendon of insertion of the variant BBm. The tendon of the extra head split into fibrous strands that formed a mesh over and between the branches of MN as well as the radial, common interosseous and ulnar arteries [Figure 7].

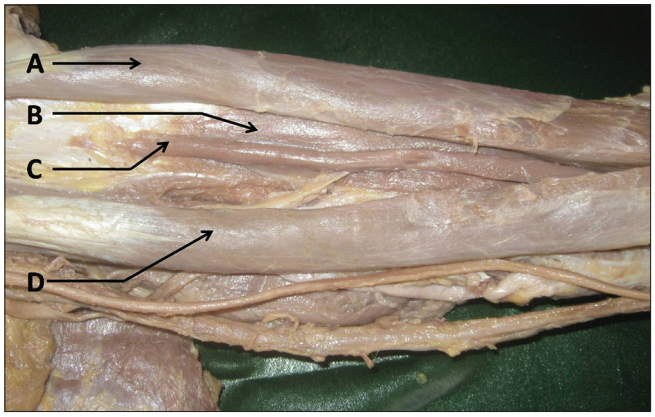

Figure 2: The photograph shows a third head of biceps brachii muscle (BBm) (C) taking origin from the anterior surface of humerus just above the origin of brachialis muscle (B). Also seen are the long (A) and short head (D) of BBm

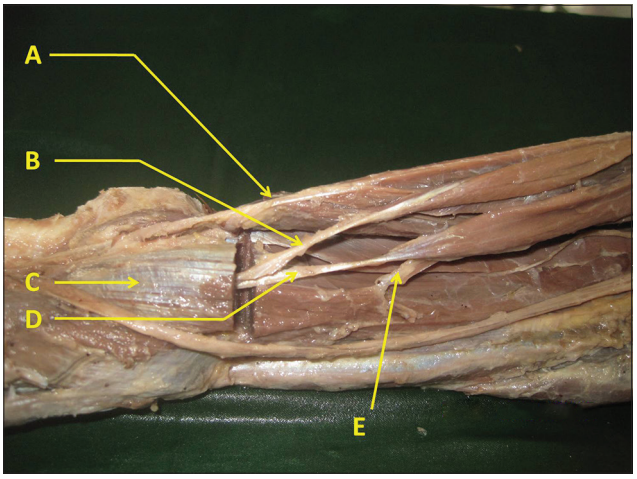

Figure 4: The photograph shows three extra bellies of insertion of biceps brachii muscle (BBm) muscle, all proximally attached to the short head of BBm (A). They were labeled as lateral (B), intermediate (D) and medial (E), according to position in the arm. Also seen is the distal part of brachialis muscle (C) which was cut to facilitate further tracing of the variant muscles

In 59 (98.3%) of ULs, out of the 60 studied the BBm was supplied by branches of musculocutaneous nerve (MCN). The extra heads of BBm received separate branches from MCN which passed between the short head and the extra head to supply them. In two of such cases a communicating branch was found passing from MCN to MN [Figure 8]. In one UL (where there was an extra head of BBm) the MCN joined the MN high up in the arm and all muscles thereafter, which are normally supplied by MCN were supplied by branches from the MN [Figure 9].

All the ULs studied were supplied by direct branches from the brachial artery, so also branches from anterior circumflex humeral, ulnar collateral or by anterior ulnar recurrent arteries.

The incidence of the variation being unilateral was found to be 10% while it being bilateral was 3.3%.

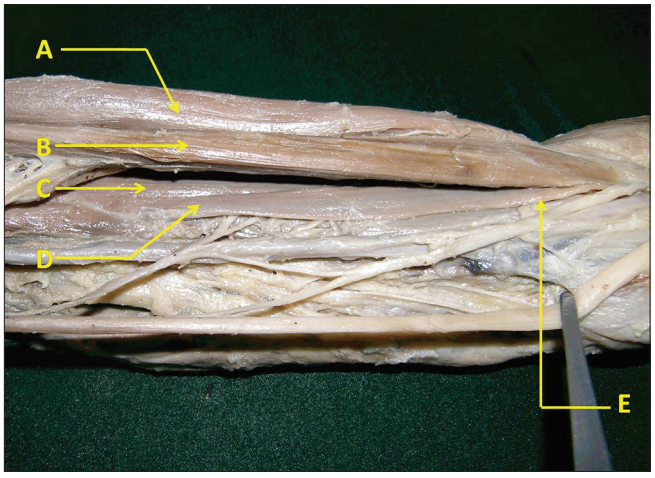

Figure 3: The photograph shows the extra head of biceps brachii muscle (BBm) (D) taking origin from the anterior surface of brachialis muscle (C). The extra head of BBm is seen uniting with the long (A) and short (B) heads at the elbow joint (E)

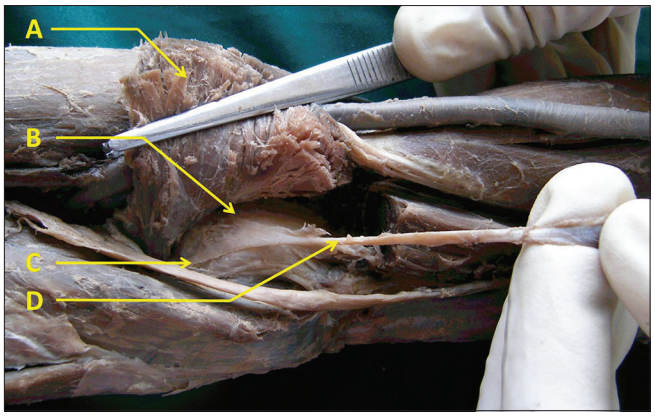

Figure 5: The photograph shows distal attachment of the intermediate belly of insertion (D) to the coronoid process of ulna (C) deep to the brachialis muscle (A). A slip of attachment (B) can be seen going toward the radius bone

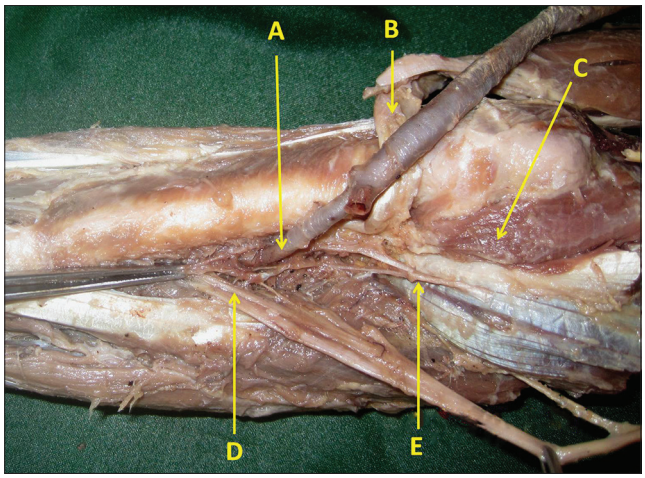

Figure 6: The photograph shows lateral belly of biceps brachii muscle (BBm) (E) passing superficial to the brachialis muscle (C), splitting into fibrous strands forming a mesh around branches of the median nerve (D) and ulnar artery (A). Also seen is the main tendon of insertion of BBm (B)

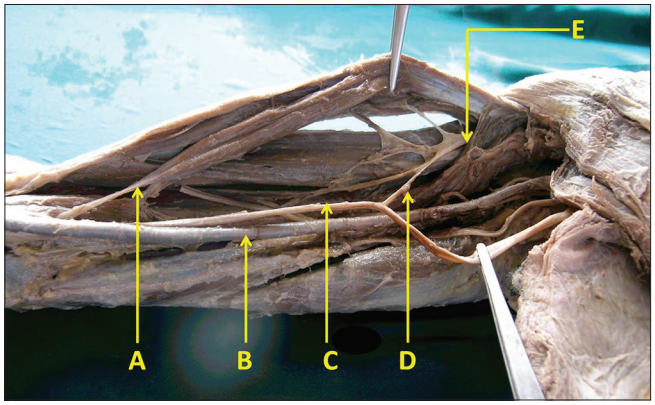

Figure 8: The photograph shows musculocutaneous nerve (MCN) and its branches (E). A communicating branch (D) is seen passing from MCN to the median nerve (C). Also seen in the photograph are third head of biceps brachii muscle (A) and the brachial artery (B)

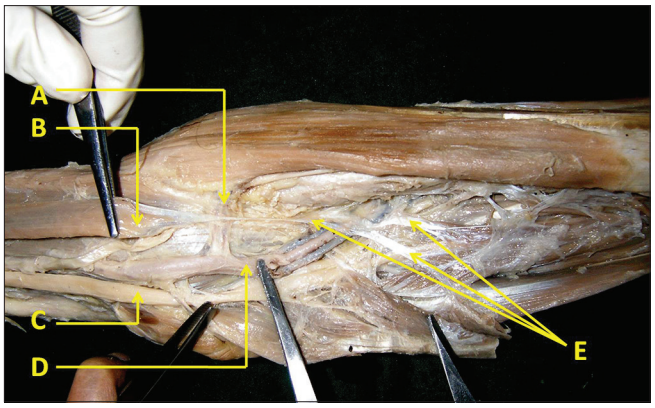

Figure 7: The photograph shows the tendon of the extra head of biceps brachii muscle (B) splitting into fibrous strands that formed a mesh (E) between the branches of the median nerve (C) as well as the radial (A), common interosseous and ulnar arteries (D)

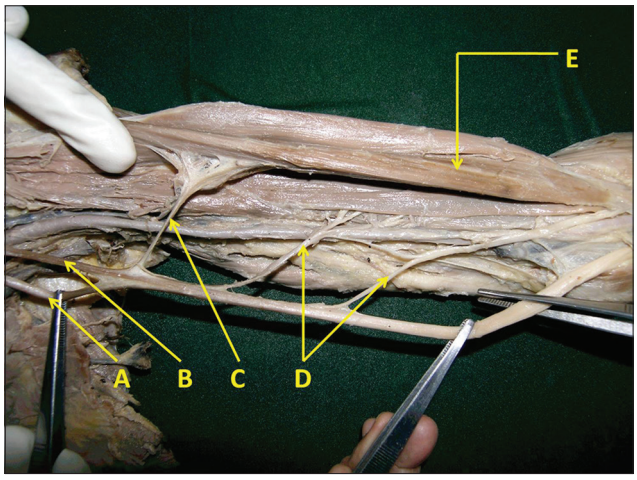

Figure 9: The photograph shows musculocutaneous nerve (B) joining the median nerve (MN) (A) high up in the arm, and all muscles of the arm thereafter being supplied by branches (D) of MN. A separate branch of MN (C) is seen supplying the third head of biceps brachii muscle (E)

DISCUSSION

The BBm is a large muscle of the upper arm that takes origin by two heads namely long and short. Normally the short head takes origin by a flattened tendon from the tip of coracoid process of scapula; the long head has a long tendon of origin from supraglenoid tubercle and passes within the capsule of the shoulder joint. It passes beneath the transverse humeral ligament, finally joins the short head about 7 cm proximal to the elbow joint.[7] The muscle forms a flattened tendon which gets attached to the posterior part of radial tuberosity. On the medial side, the muscle gives a broad expansion called bicipital aponeurosis, which fuses with the deep fascia over the flexor muscles of the forearm.[7]

Bryce stated that variability encountered in BBm could be due to its characters being acquired late in human phylum. It was originally a single headed muscle arising from coracoid bone merged below with brachialis, inserted by a common tendon to both bones of the forearm. A second head at the base of coracoid bone soon developed. This today represents the long head of BBm. Later the radial head of insertion became dominant while the fibers passing through semilunar fascia (bicipital aponeurosis) represent the ulnar contingent of the muscle. The tendon has been observed in some bodies to continue to give slips to coronoid process.[1]

The variations in BBm have been observed mainly in number of heads of origin/PA. Variations in tendon of insertion/DA are comparatively rare. In this study, the variations in BBm have been categorized as variations in heads of origin and variations in insertion.

Table 3 depicts the incidence of extra heads of origin/PA of BBm reported by various authors in comparison with this study.

Table 3: Comparison of percentage of incidence of extra head of origin/PA of BBm by different authors compared to present study

Author	Percentage of incidence of extra head of origin of BBm	
	3rd head of BBm	4th head of BBm
Ambali *et al.*[8]	11.53	1.3
Avadhani and Chakravarthi[5]	16.67	2.08
Cheema and Singla[9]	2.3	Nil
Kervancioglu and Orhan[10]	8.33	Nil
Kumar *et al.*[11]	3.3	Nil
Lokanadham and Devi[6]	5	Nil
Present study	13.3	Nil

BBm: Biceps brachii muscle; PA: Proximal attachment

The third head is the most commonly reported of the extra heads of origin of BBm, the fourth head being comparatively rare. Most authors have observed that the third head is mostly seen taking origin from the anterior surface of humerus, medial or lateral to attachment of coracobrachialis muscle.[3,12-14] Present study also reports 5 ULs showing similar origin of third head of BBm.

This study reports the origin of third head of BBm from the capsule of the shoulder joint in two limbs. In one case, the capsular origin was seen blended with a short head in such a way that separation between the two heads was almost imperceptible. Should such a capsular attachment be considered as an extension of attachment of the short head of BBm? A separate third head of BBm from capsular ligament of the shoulder joint has also been reported by Macalister.[15] Warner described a case where recognition and mobilization of an accessory long head of the BBm was necessary during surgery for dislocated shoulder, for adequate exposure of the joint through a deltopectoral incision.[16] A similar mobilization may be needed in case of presence of third head from the capsule of the shoulder joint as described in the present study.

Origin of third head from the anterior surface of brachialis muscle has been described.[8,10,17] In this study also one UL showed similar attachment of the extra belly to brachialis muscle. As stated by Bryce the BBm was originally a single headed muscle that merged with the brachialis and was attached to both bones of the forearm by a common tendon.[1] This can explain the occasional finding of origin of third head from brachialis muscle being a phylogenic fallback on an earlier attachment in evolution. Presence of a humeral head is a normal feature in gibbons; however, they have no attachment to coracoid process in the form of short head of BBm. Gibbons are known expert brachiators. Brachiators are primates that use their arms to move from one branch of a tree to another for locomotion. Such animals have powerful arms. Michilsens *et al*. state that by attaching one head of BBm to the humerus, the action of BBm at the elbow joint becomes more powerful.[18] The gibbons need the muscles at the elbow to be able to work primarily against the gravitational forces to move the body "up and forward" during brachiation. Therefore, flexor muscles in the elbow have to be developed. He states that the absence of attachment to coracoid process however weakens the flexor action of BBm at the shoulder joint.

Unless symptomatic the extra head of origin of BBm may not be detected. However, if the extra head is sufficiently large, it may provide added strength to the BBm during the movements of supination and flexion. The knowledge of their existence is important for correct identification during imaging or surgery.[4] The supernumerary head has also been associated with unusual bone displacement subsequent to fracture.[12]

While much discussion has occurred regarding extra heads of origin of BBm, reports of extra heads or bellies of insertion/DA are few [Table 4]. Some authors have included muscles taking origin from short head or long head of BBm as third or fourth heads of BBm.[5] Since the description of origin of these bellies (short and long) is consistent with the description in standard texts, and the variation has been seen in the mode of insertion of the said muscles, in this study they have been classified into the category of extra bellies of insertion.[7]

In all cases, where extra bellies of insertion have been observed by other authors, the DA of the extra belly was observed to be proximal to the elbow joint. In the present case, two of the extra bellies of insertion were distally attached to coronoid process, radial tuberosity, radius and/or ulna. Such extra bellies of insertion can aide in the flexion action at the elbow joint. The existence of attachments observed to coronoid process, radius and ulna bones can be parts of ulnar and radial contingents of the single headed BBm described by Bryce earlier.[1]

The tendon of insertion of BBm is of clinical interest as it can show partial or complete tears which need to be differentiated from any naturally occurring anatomical variations such as the above described extra bellies of insertion. During the study of arm region on magnetic resonance imaging (MRI) a hypointense structure is sometimes observed near the bicipital tendon. This structure can be the additional head of BBm, but can

Table 4: The origin and insertions of the extra bellies of insertion/DA of BBm reported by different authors in comparison with the present study

Authors	Origin	Insertion
Avadhani and Chakravarthi[5]	4th head from short head of BBm	Shaft of humerus above the insertion of coracobrachialis muscle
Swamy *et al.*[19]	3rd head from medial border of short head of BBm	Into the medial intermuscular septum
Present study	3rd head from medial border of short head of BBm, subdivided into	
	Medial belly	Attached to the fascia covering brachialis muscle
	Intermediate belly	Formed a thin long tendon that distally split into two slips, one attached to the radial tuberosity, the other to the coronoid process of ulna
	Lateral belly	Split into several fibrous strands which spread out in the space between the radius and ulna, attaching to both the bones

DA: Distal attachment; BBm: Biceps brachii muscle

be misinterpreted as evidence of partial tearing of the biceps tendon.[4] Chew and Giuffrè state that the MRI of this region is difficult due to the complex anatomical course of the tendon.[20] Placing the patient in the prone position, with arm overhead, elbow flexed to 90° with the forearm supinated which is referred by Chew and Giuffrè as "FABS" position (flexed elbow, abducted shoulder, forearm supinated), helps to provide a detailed view of the distal biceps tendon preventing any misinterpretation as described by Gheno *et al*.[4] Chew and Giuffrè also state that ultrasonography, which is less expensive and more rapidly performed can also be used for studying the distal biceps brachii tendon.[20]

Ashiq and Arulmoli have reported finding of an unusual inferolateral third head of BBm taking origin from humerus and joining the tendon of the main BBm, also contributing fibers to medially placed bicipital aponeurosis.[21] An expansion from the extra head of BBm formed the lateral bicipital aponeurosis, which covered the common extensor origin and joined the antebrachial fascia. In this study, the authors report the finding of two cases where the extra bellies gave expansions distally, besides contributing to the formation of the main tendon of BBm. In one of the cases, the expansions formed a mesh around the ulnar artery and MN while in the other case the mesh also enclosed branches of radial and common interossoues arteries. Such fibrous bands can compress the nerves and arteries passing between them resulting in neurovascular compression disorders. Sawant has described compression of the brachial artery and MN by third head of BBm, while Aggarwal *et al*. have discussed the possibility of compression of MCN between the third and fourth heads.[3,14] While descriptions of third and fourth heads and neurovascular compression by them are found in literature, the authors have found no description of fibrous extensions of BBm tendon between the radius and ulna as described in this study. These fibrous extensions seem unique and hitherto unreported.

Supernumerary heads of BBm have been associated with MCN variations. The passage of MCN between the short and extra head of BBm can create a potential site of compression during contraction of BBm. This is especially true in hypertrophied BBm as seen in case of a professional body builders.[3]

A communicating branch between MCN and MN as observed in two cases in this study, which has also been described by Kumar *et al*.[11] Yogesh *et al*. have described a case where the MCN was absent and the MN supplied all the muscles of the anterior compartment of arm as seen in one UL in the present study.[22] However, in this study the MCN was present, but joined the MN high up in the arm.

New classification of Biceps brachii muscle suggested

Many authors have reported finding of one extra belly labeled as third head of BBm. Authors finding two extra bellies in the same UL, have reported finding of third and fourth heads of BBm.[5,8] Which of the two extra heads here should be labeled as the third head? The anatomy behind the classification of either of the extra heads as third or fourth is not clear. Gray's Anatomy states that in 10% cases a third head arises from superomedial part of brachialis muscle.[7] In this study, eight BBms showed the presence of extra bellies. One UL out of these showed three extra bellies which took origin from the short head of BBm itself. Thus to avoid any ambiguity, it is suggested that the extra bellies of BBm be classified as bellies of origin/PA and bellies of insertion/DA. Thus, an extra muscle belly that is separately attached to capsule of the shoulder joint and later joining the main tendon of BBm is an extra belly of origin. To avoid the confusion of third or fourth heads it is suggested that each belly of origin should be further specifically referred to as brachial, humeral, capsular heads according to their PA, doing away with the terms third, fourth or fifth heads completely. A muscle belly having PA to BBm itself, but a DA which is separate from the main tendon of BBm is an extra belly of insertion. Depending upon whether the extra belly took origin

Table 5: The suggested classification of the extra bellies of BBm

Extra bellies of BBm	
Extra belly of origin	**Extra belly of insertion**
Capsular head Brachial head Humeral head	From short head of BBm From long head of BBm

BBm: Biceps brachii muscle

from short head or long head, it can be referred to as extra belly of insertion from short head or from long head respectively [Table 5].

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