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Radial Nerve Innervation of the Brachialis Muscle in the Ghanaian Population

A. A. Brown[1], N. O. Dike[2]

[1] *Department of Anatomy and Cell Biology, School of Medical Sciences, University of Cape Coast, Cape Coast, Ghana*

[2] *Department of Medical Education, School of Medical Sciences, University of Cape Coast, Cape Coast, Ghana*

CORRESPONDING AUTHOR:
Ato Ampomah Brown
Department of Anatomy and Cell Biology
School of Medical Sciences
University of Cape Coast
Cape Coast, Ghana
E-mail: a.a.brown@uccsms.edu.gh

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SUMMARY

Background. The dual innervation of the brachialis muscle by musculocutaneous and radial nerves has been described and adopted, despite being traditionally known to have singular innervation as other flexors in the anterior compartment of the arm. However, the prevalence, course and patterns of distribution of its radial innervation varies in different population, and in the Ghanaian population, no information has been described.

Methods. Thirty-eight (n = 38) cadaveric upper limbs (18 paired and 2 single), routinely used by medical students at the Department of Anatomy and Cell Biology, University of Cape Coast, Ghana, were dissected. The brachialis muscle was exposed in its entire length, and the radial nerve exposed in its course from the spiral groove to the elbow, noting the presence or absence of radial branches to the muscle, number of branches, nature and pattern of branching, level at which the branching occurred, and the level at which branches pierced the muscle.

Results. All specimens were innervated by the musculocutaneous nerve, 76.3% had dual innervation. The radial nerve originated and pierced the muscle at varying levels. Sixty nine percent had solitary radial nerve fibre, and 31.0% had multiple branching patterns. None had more than 2 branches of the radial nerve. The prevalence of dual innervation of the brachialis muscle in the Ghanaian population appears to be high, and the pattern of branching and distribution of the radial nerve fibres differ from those reported in earlier studies.

Conclusions. This knowledge is invaluable in choosing surgical approaches so as to minimize denervation of the brachialis muscle.

KEY WORDS

Brachialis; Ghana; humerus; musculocutaneous nerve; radial nerve.

BACKGROUND

The brachialis muscle is located in the anterior compartment of the arm and is a flexor of the elbow joint. Muscles in the anterior compartment of the arm are typically innervated by the musculocutaneous nerve. Despite being traditionally known to have singular innervation as other flexors in the anterior compartment of the arm, the brachialis muscle is now being described to receive dual innervation by musculocutaneous and radial nerves (1, 2). The first mention of the dual innervation of the brachialis muscle was about a century ago (3). Over the decades that followed, there has been much debate on this issue. The consensus in recent times appears to lead in the direction that the brachialis muscle has dual innervation, with some standard anatomy text books now indicating that the brachialis muscle is innervated by both the musculocutaneous and the radial nerve.

Various studies have however shown that the prevalence of radial nerve innervation varies from population to population, with ranges from 30-100% (4). With this wide range, it is important that particular populations have adequate data

on the prevalence and nature of the radial nerve branching patterns. The knowledge of the course and the pattern of distribution of the radial nerve branches, with regards to brachialis muscle, is of clinical importance as it informs surgeons on the best surgical approaches to minimize injury to these nerve fibres. There is, however, no information of the frequency of radial nerve innervation of the brachialis, nor its branching pattern within the Ghanaian population. This study therefore seeks to address this gap in knowledge.

MATERIALS AND METHODS

This study was conducted in the Department of Anatomy and Cell Biology, University of Cape Coast, using 38 cadaveric upper limbs (18 paired and 2 single), that are routinely used by medical students during their dissection session. These cadavers were donated by the state to the Department and their use for medical training and research is covered by the Anatomy Act of Ghana 1965. The study protocol also conformed to the ethical guidelines of the outlined Declaration of Helsinki of 1975 and its subsequent editions.

Cadavers that were found to have upper limb deformities or trauma were excluded from the study.

Skin, subcutaneous fat, and superficial fascia of the upper limb were dissected; the full length of the brachialis muscle was exposed and measured, and their lengths divided into three equal parts. These parts of the muscles were subsequently referred to as proximal, middle, and distal levels (**figure 1**).

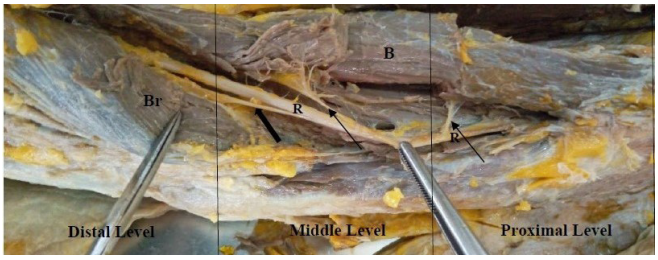

Figure 1. A photograph of the left upper limb showing two nerve branches (thin black arrows) arising from the radial nerve (R) entering the brachialis muscle (B) in the proximal and middle levels. Also shown is the brachioradialis muscle (Br) with a radial nerve branch also entering into it (thick black arrow).

The radial nerve was identified between the brachialis and the brachioradialis muscle. The nerve was then carefully dissected to expose its course from the spiral groove on the humerus, to the elbow region. The following were noted and documented: the presence or absence of radial branches to the brachialis muscle, the number of branches present, the nature and pattern of branching, the level at which the branching occurred, as well as the level at which branches pierces the muscle. The origin of the nerve branches and their subsequent sites of entry were documented, in relations to the levels of the muscle as previously described.

The musculocutaneous nerve was also identified as it descends through the interval between biceps brachii and brachialis muscle, with the presence or absence of branches to the brachialis muscle noted.

RESULTS

The musculocutaneous nerve was found to innervate the brachialis muscle in all specimen (100%), while the prevalence of radial nerve innervation of the brachialis muscle was found to be 76.3% (29 specimen). Of the 38 dissected specimen, 18 pairs (n = 36) were from the same cadaver, with radial innervation bilaterally present in 10 pairs (55.6%) and bilaterally absent in 1 pair (5.6%) (**table I**).

The branches of the radial nerve were found to originate and pierce the brachialis muscle at various levels. Eleven (28.9%) radial nerve branches pierced the muscle at its middle aspect while 24 (63.2%) of nerve fibres entered at the distal level (**table II**). In 69.0% (20 specimen) of specimen, a solitary radial nerve fibre was observed, while in 31.0 % (9 specimen) 2 radial nerve branches were observed, and branches of more than 2 were not observed in any specimen. There were 4 specimen that had their radial nerve branches originate at different levels.

In our study, 12 (31.6%) radial nerve branches were observed penetrating the brachialis muscle by coursing straight, 16 (42.1%) of the branches descended before

Table I. The laterality of radial nerve innervation of the brachialis muscle.

Bilaterally present	Unilateral (right)	Unilateral (left)	Bilaterally absent
10 (55.6%)	3 (16.6%)	4 (22.2%)	1 (5.6%)

Table II. The levels of origin of the radial nerve branches and their entry into the brachialis muscle.

	Proximal level	Middle level	Distal level
Level of origin	4 (10.5%)	12 (31.6%)	22 (57.9%)
Level of entry	3 (7.9%)	11 (28.9%)	24 (63.2%)

piercing the muscle obliquely, while 10 (26.3%) of the radial nerve branches ascended (recur).

DISCUSSION

In this study, the musculocutaneous nerve was found to innervate the brachialis muscle in all cases and therefore corroborates what is widely documented in literature. The radial nerve was also found to innervate the brachialis muscle in 76.3% of cases. This finding is comparable to the observation of previous studies. The high incidence of dual innervation in this study, gives credence to the assertion by Bendersky and Bianchi (3) that although the frequency of dual innervation varies from population to population, the reported frequencies are generally high, which appears to be the case in the Ghanaian populace.

It was noted that the branches of the radial nerve arose at different levels with regards to the length of the brachialis muscle: 10.5% of the branches occurred at the proximal level, 31.6% were observed at the middle level while 57.9% of branches were located at the distal level. It therefore appears that the radial nerve branches which innervate the brachialis muscle, usually originates from the nerve in the distal part of its course in the arm. This observation concurs with the findings of Blackburn *et al.* (5) who found that the radial nerve branches to the brachialis muscle originate from two distinct level, a proximal and distal levels, with the distal being the more common of the two (3).

In 69.0% (n = 20) of cases, a solitary radial nerve branch was observed, while 2 nerve branches were observed in 31.0 % (n = 9) of cases. This finding contrasts those of Awori and Inyimili (6) and Mahakkanukrauh and Somsarp (7) who identified only one radial nerve branch in 100% of their specimen. Radial nerve branches of more than 2, were not seen in our study, contrary to the findings of other researchers who had observed up to 3 branches in a small percentage of their specimen (4, 8). Of the 9 cases that had 2 radial nerve branches, 4 (13.8%) had their branches occurring at 2 different levels, with each having one of its branches always given off at the distal level. This finding suggests that although the radial nerve courses along almost the entire length of the brachialis muscle, it rarely and infrequently gives off multiple branches into the muscle as would have been expected. Even in cases where there are multiple branches, they rarely exceed 2 branches.

In our study, the radial nerve branches were observed to enter/pierce the brachialis muscle at the proximal level in 7.9% of the cases, 28.9% at the middle level, and 63.2% at the distal level. These finding are similar to those of Gaur *et al.* (8). They observed that 12.5% of the nerve branches pierced the proximal part of the muscle, 28.1% entered the middle part, while 59.4% were located in the distal aspect of the muscle. There are other studies that have however found the site of entry to be limited to the middle and distal portions of the muscle (3, 4, 9). In all these studies, including ours, the distal part of the muscle was the commonest site of entry for the radial nerve branches.

When comparing the levels at which nerve branches originated from the radial nerve, with the levels at which they penetrated the muscle, it was observed that with the exception of 3 branches, all the nerves arose and entered the muscle at the same level. In all 3 cases, the branching occurred near the junction of the middle and distal levels. Our findings are similar to those by Bendersky and Bianchi (3), who noted that radial nerve branches enter the muscle not too far from the level they arose.

The branches of the radial nerve that innervated the brachialis muscle, course differently before entering the muscle. In 31.6 % of cases, nerve branches were found to course straight into the muscle, in 42.1% of cases they descended and entered the muscles in an oblique manner, while in 26.3% of the specimen the nerve branches were found to recur or ascend. Similar description has been observed in other studies (5, 7, 9). Contrary to the findings of our study, Blackburn *et al.* (5) and Prakash *et al.* (9) reported that the majority of radial nerve branches went straight into the brachialis muscle. Mahakkanukrauh and Somsarp (7), were the first to describe recurrent branches of the radial nerve into brachialis muscle. They postulated that this course may be due to differential growth of the lateral intermuscular septum, such that the radial nerve was pulled distally and a branch arising from it to supply the brachialis had to recur. Although the branches of the radial nerve were found to ascend and descend as already noted, these branches appeared not to travel far from their points of origin to enter the muscle.

In our study, the number of branches of radial nerve, level of branching, entry into the muscle, and the course of the radial nerve were not symmetrical in both limbs, with the exception of 2 pairs. Of the 2 pairs, 1 pair of limbs was found to have a single descending radial nerve branch which originated and entered the brachialis muscle at the distal level. The other pair was found to have 2 radial nerve branches, with one recurring and the other descending. Both branches originated and pierced the muscle at the distal level.

In view of the high incidence of radial nerve innervation of the brachialis muscle and the varying nature of its course and pattern of distribution, some authors have proposed a surgical approach to the humerus that entails splitting the brachialis in the midline, on basis that, the midline of the muscle represents an internervous plane, with the musculocutaneous nerve innervating the medial portion of the muscle and the radial nerve innervating the lateral portion (3, 4, 7). However, in cases where the brachialis muscle is innervated solely by the musculocutaneous nerve, this approach puts the lateral half of the muscle at risk of denervation (4, 7). Other authors have

Table III. Comparison of data from previous studies with present study.

	Prevalence	Site of entry	Number of branches	Pattern of distribution
Present study	76.3%	Proximal, Middle and Distal	Multiple branches (up to 2 branches)	Straight, Descending and Ascending (recurrent)
Mahakkanukrauh and Somsarp (6)	81.6%	Middle and Distal	Solitary branch	Straight, Descending and Ascending (recurrent)
Prakash *et al.* (8)	72.0%	Middle and Distal	---	Straight and Zig Zag pattern
Bendersky and Bianchi (1)	65.0 %	Middle and Distal	Multiple branches	---
Ilayperuma *et al.* (2)	83.33%	Middle and Distal	Multiple branches (up to 3)	Straight and Descending
Gaur *et al.* (7)	87.09%	Proximal, Middle and Distal	Multiple branches (up to 3)	---

recommended that the distal humerus can be approached surgically by splitting the plane between the brachioradialis and brachialis muscle where the radial nerve is known to lie (10), being mindful of to identify the branches to the brachialis muscle to preserve them (4, 11). Even though there is much mention of preserving the radial nerve during surgical manipulation, there appears to be scant information in the literature on possible clinical sequelae following this denervation (3).

In the study by Bendersky and Bianchi (3) that utilized both anatomical dissection and neurophysiological methods (upper limb electromyography and nerve conduction velocity), they found a great disparity in the prevalence of radial nerve innervation of the brachialis muscle depending on the method being used. Using the neurophysiological approach, they obtained a prevalence of 90% and while a prevalence of 65 % was recorded in the anatomical method. They postulated that the wide variation in frequencies may due to the presence of minute radial nerve branches that cannot be detected with dissection.

From the findings of our study, 1 in every 4 Ghanaian may be at risk of radial nerve denervation of the brachialis muscle if the anterior approach is used. Splitting of the plane between the brachialis and brachioradialis muscle may probably be the more appropriate surgical approach to the distal humerus in the Ghanaian population, although it may be more time consuming as it requires surgeons to meticulous seek and perverse the radial nerve branches.

The authors recognize some limitations to our study, such as the inability to perform gender-based analysis due to a small number of female cadavers. Also, intra-observer and inter-observer reliability were also not carried, these could have increased the validity of our study.

CONCLUSIONS

The prevalence of dual innervation of the brachialis muscle in the Ghanaian population appears to be high and the pattern of branching and distribution of the nerve fibres has been found to differ from those reported in earlier studies (**table III**). Consequently, knowledge by surgeons with regards to this branching pattern cannot be overemphasized as it will be invaluable in choosing surgical approaches in mid-shaft or distal humeral procedures. Although, the effect of musculocutaneous denervation of the brachialis has been described, there is paucity of literature on the magnitude of effect when its radial innervation is compromised, necessitating further observation and study. This knowledge will aid surgeons minimize denervation of the brachialis muscle, a prime flexor of the elbow joint, whose denervation and subsequent weakening can significantly impact and limit the performance of everyday activities.

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None.

DATA AVAILABILITY

Data are available to the following repository link: ir.ucc.edu.gh/xmlui.

CONTRIBUTIONS

AAB: design of the study, data analysis, and writing of the initial draft. NOD: study conceptualization and revision of the manuscript. AAB, NOD: dissection and final manuscript approval.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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