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Original Article

# A morphologic and histologic study of the radial nerve and its branches at potential compression sites

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**الملخص**

**أهداف البحث:** بحثت هذه الدراسة في الاختلاف في مستوى انتهاء العصب الكعبري، والقياس الشكلي للعصب الكعبري، وفروعه في مواقع الضغط المحتملة. بالإضافة إلى ذلك، قمنا بتحليل رقمي لمقاطع نسيجية للعصب الكعبري، والفرع السطحي للعصب الكعبري والعصب بين العظام الخلفي.

**طرق البحث:** أجرينا هذه الدراسة على ١٤ جثة لبالغين محفوظة بالفورمالين. تم قياس أطوال العصب الكعبري، والفرع السطحي للعصب الكعبري والعصب بين العظام الخلفي إلى أن يصل إلى مواقع الضغط المحتملة باستخدام المعالم السطحية الهيكلية المناسبة كنقاط مرجعية. نسيجيا، قمنا بتقييم المناطق ذات الحزم وغير ذات الحزم وعدد المحاور لكل عصب. تم تحليل جميع المعلومات إحصائيا.

**النتائج:** وجدنا اختلافا في انقسام العصب الكعبري بالنسبة إلى خط ثنائي اللقيمات. ولكن الفروع الطرفية للعصب الكعبري لها مسار ثابت في الساعد. نسيجيا، كان هناك اختلاف كبير بين المناطق ذات الحزم وغير ذات الحزم للعصب بين العظام الخلفي. لم يكن هناك اختلاف جذري بين المحاور العصبية الكلية للفرع السطحي للعصب الكعبري والعصب بين العظام الخلفي. أخيرا، لاحظنا أن هناك اختلاف في الطول العضلي للعصب بين العظام الخلفي داخل العضلة الضاغطة، وأن لدى الفرع السطحي للعصب الكعبري أكبر عدد من الحزم بالمقارنة بالعصب الكعبري والعصب بين العظام الخلفي.

**الاستنتاجات:** في هذه الدراسة، لدى العصب الكعبري والعصب بين العظام الخلفي قياس متغير أكثر بالمقارنة بالفرع السطحي للعصب الكعبري. يوفر التقييم النسيجي ومقاييس هذه الأعصاب في مواقع الضغط المحتملة دليلا للجراحين لتخطيط إجراءات إعادة بناء الأعصاب.

**الكلمات المفتاحية:** شكلي؛ علم الأنسجة؛ العصب الكعبري؛ العصب بين العظام الخلفي؛ الفرع السطحي

**Abstract**

**Objectives:** This study examined variations in the termination level of the radial nerve (RN) and the morphometry of the RN and its branches at potential compression sites. Additionally, we digitally analysed histological sections of the RN, the superficial branch of the radial nerve (SBRN), and the posterior interosseous nerve (PIN).

**Methods:** We conducted this study on 14 formalin fixed adult cadavers. The lengths of the RN, SBRN, and PIN were measured up to potential compression sites, using appropriate surface skeletal landmarks as reference points. We histologically evaluated the fascicular and non-fascicular areas and the number of axons in each nerve. All parameters were statistically analysed using a paired t-test.

**Results:** We found variations in the bifurcation of the RN with respect to the biepicondylar line (BEL). However, the course of RN terminal branches was constant in the forearm. There was a significant histological difference between the fascicular and non-fascicular areas of the PIN. There was no significant difference in the total number of axons in the SBRN and PIN. Finally, we observed that the intramuscular length of the PIN within the supinator muscle was variable and that the SBRN had more fascicles compared to the RN and PIN.

**Conclusions:** In our study, the RN and PIN had more variable morphometry compared to that of the SBRN. The histologic evaluation and quantification of these

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nerves at their potential compression sites could serve as a guide for surgeons planning nerve reconstruction procedures.

**Keywords:** Histology; Morphologic; Posterior interosseous nerve; Radial nerve; Superficial branch



## Introduction

The radial nerve (RN), a branch of the posterior cord of the brachial plexus (C5–C8, T1), runs posterior to the humerus in the spiral groove. It pierces the lateral intermuscular septum, lies anterior to the humeral lateral epicondyle,[1] and is prone to entrapment where it pierces the lateral intermuscular septum.[2] At the elbow, it divides into a superficial and a deep branch, the posterior interosseous nerve (PIN). In the arm, the RN supplies the triceps brachii, brachialis, brachioradialis, and extensor carpi radialis longus muscles.[3]

The superficial branch of the radial nerve (SBRN) runs through the forearm, concealed beneath the brachioradialis. It crosses it at approximately 8 cm from the tip of the styloid process to supply the skin on the dorsum of the hand. The PIN pierces the supinator muscle and lies between the superficial and deep muscles of the back of the forearm.[4] Compression of the SBRN can occur because of pressure from a tight handcuff, external trauma, or iatrogenic causes.[5–7] Morphological variations of the brachioradialis muscle also play a role in nerve entrapment and nerve transfer surgeries.[8–10]

RN compression can occur in five different regions within the radial tunnel,[11] and the arcade of Frohse, formed by the superficial layer of the supinator muscle, is among them.[12,13] RN compression can occur as a result of overuse because of direct trauma, lacerations, or post-operative complications.[14]

Knowledge of RN anatomy is essential when performing surgery such neurorrhaphy or nerve blocks and to understand nerve injury recovery.[15]

RN neuropathies at the mid humeral level usually have good prognoses. However, recovery is dependent on age, gender, defect size, and follow-up duration.[16] Research has proven that fascicle matching during nerve grafting results in better functional recovery.[17]

Therefore, we aimed to study variations in the RN termination levels. We studied the morphometry of its terminal branches as they related to potential compression sites. We digitally evaluated histological sections of the RN, SBRN, and PIN. We digitally calculated the fascicular and non-fascicular areas and the number of axons and compared their differences. Determining the number of fascicles at compression sites could help surgeons make decisions about fascicle matching during grafting surgeries.

## Materials and Methods

We conducted this study on 14 formalin-fixed adult cadavers procured from the Department of Anatomy. The Institutional Ethics Committee (IEC) approved the study protocol and allowed the research to be conducted at our institute (ID 490/2019).

We dissected all the upper limbs meticulously and identified the RN in the arm, noting the point where it pierced the lateral intermuscular septum. We traced its further course between the brachialis and brachioradialis muscles. We dissected and identified its bifurcation into superficial and deep branches at the elbow. The SBRN was outlined under the cover of the brachioradialis muscle up to its terminal branches in the hand. The deep nerve, or PIN, was traced up to the upper border of the supinator muscle. For the morphometry, we chose potential compression sites such as the lateral intermuscular septum, the upper limit of the supinator muscle, and the wrist.[2,5,12] We considered the biepicondylar line (BEL), Lister's tubercle, and the radial styloid process as the surface skeletal landmarks. We noted whether the RN bifurcated above, at, or below the BEL level.

We used sliding callipers, thread, and a measuring tape to measure the distances. We measured the length of the RN from where it pierced the lateral intermuscular septum up to its bifurcation. We measured the length of the PIN from its origin up to where it pierced the supinator muscle and between the entry and exit points of the supinator muscle. We also measured PIN length from its last branch to Lister's tubercle and SBRN length from the point where it became cutaneous up to the radial styloid process.

We noted the distance of the first SBRN branch from the radial styloid process. We measured the diameters of the RN, PIN, and SBRN at their potential compression sites.

We processed the transverse sections of the RN, PIN, and SBRN cut with a 5-mm thickness which were taken from their potential compression sites for histologic evaluation. Two slides of each prepared section were stained using Hematoxylin and Eosin (H & E) for digital quantification. We used cellSens imaging software (Olympus Corporation, Japan) to count the total number of fascicles in each section and to quantify the number of axons in each fascicle and in the whole nerve section (Figure 1).

We compared the number of axons between the two terminal branches. We also measured the total fascicular and non-fascicular areas of each section and compared them statistically using a paired t-test (Figure 2).

## Results

Of the 14 cadavers, 10 were males and four were females of ages ranging from 40 to 75 years. In all the limbs examined, we identified the RN between the brachialis and brachioradialis in the distal arm. The RN had a variable length in the anterior compartment of the arm, ranging from 3.1 cm to 10.5 cm. The RN bifurcated at a variable distance with respect to the BEL. Of the 28 upper limbs observed, in 18 upper limbs, the RN bifurcated above the BEL level; in six

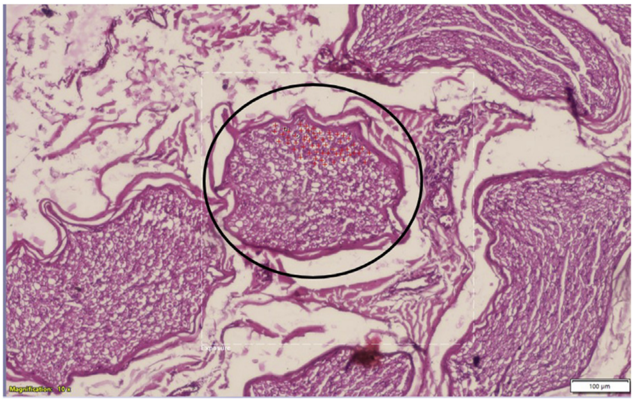

**Figure 1:** Photomicrograph of the radial nerve (Haematoxylin and Eosin stained, 10× magnification), depicting the counting of axons (red cross marks) in a single fascicle (black circle)

limbs, it bifurcated at the BEL level; and in four limbs, it was below the BEL level.

The terminal branches of the RN had a constant course in the forearm. In all the upper limbs examined, the PIN pierced the supinator muscle and entered the back of the forearm to innervate the extensor muscles. The SBRN traversed under the cover of the brachioradialis muscle to innervate the dorsum of the hand.

The RN had a mean length of 6.51 ± 2.08 cm from where it pierced the lateral intermuscular septum until its bifurcation. The PIN length from its origin until where it pierced the supinator muscle ranged from 2.2 cm to 9.9 cm, with a mean length of 5.11 ± 2.11 cm. The length traversed by the PIN in the supinator muscle ranged from 2.4 cm to 6.5 cm, with a mean length of 4.08 ± 1.17 cm. The mean length of the PIN from its last branch to Lister's tubercle was 9.58 ± 2.79 cm (range 5.3−13.7 cm). The SBRN length from where it became cutaneous with respect to the radial styloid process was found to be 11.52 ± 4.29 cm. The mean distance between the first branch of the SBRN until the radial styloid process was found to be 5.5 ± 1.45 cm. The RN diameter was 0.32 ± 0.06 cm. The SBRN diameter was 0.2 ± 0.073 cm, and the PIN diameter was 0.23 ± 0.05 cm.

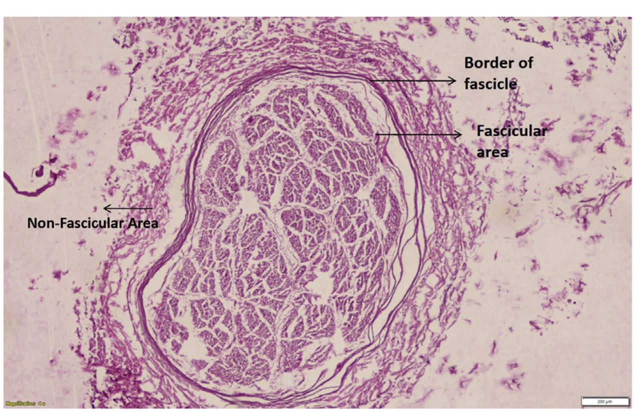


**Figure 2:** Photomicrograph of a single fascicle in the radial nerve (Haematoxylin and Eosin stained, 4× magnification), measuring the fascicular and non-fascicular areas.

In the histological analysis, the mean fascicular area of the RN was 0.0238 ± 0.0056 $cm^2$, and the non-fascicular area was 0.0491 ± 0.0114 $cm^2$. The fascicular area of the PIN was 0.0111 ± 0.00299 $cm^2$, and the non-fascicular area was 0.0306 ± 0.00915 $cm^2$. The fascicular area of the SBRN was 0.00762 ± 0.00462 $cm^2$, and the non-fascicular area was 0.0120 ± 0.00157 $cm^2$. In all the sections examined, the non-fascicular area was larger than the fascicular area. Statistically, there was no significant difference between the fascicular and non-fascicular areas of the RN and SBRN. A significant difference was noted only in the case of the PIN ($p < 0.001$).

The number of fascicles in the RN ranged from one to seven (mean 4.3). The number of fascicles in the PIN ranged from two to seven (mean 5.4). The number of fascicles in the SBRN ranged from six to 13 (mean 7.8). The total number of axons in each fascicle of the RN ranged from a maximum of 3227 to a minimum of 261 (mean 1015.72 ± 766.51). The total number of axons in each fascicle of the PIN ranged from a maximum of 3353 to a minimum of 68 (mean 599.51 ± 781.68). The total number of axons in each fascicle of the SBRN ranged from a maximum of 1172 to a minimum of 92 (mean 381.46 ± 223.70).

The total number of axons in a section of RN was 4558.25 ± 2764. The total number of axons in a section of PIN was 3237.4 ± 649.71. The total number of axons in a section of SBRN was 2994.6 ± 716.47. When we observed the total number of axons in the terminal branches of the RN, we did not find a statistically significant difference between the two.

## Discussion

In the present study, we studied the morphometry and histologic evaluation of the RN, PIN, and SBRN at their potential compression sites.

A study by Artico and colleagues revealed that the RN pierced the lateral intermuscular septum at a distance of 11.4 ± 1.2 cm from the lateral epicondyle.[18] Wegmann and colleagues, in their study of the radial nerve course to identify a safer zone for lateral pin placement, revealed a variable RN course in the arm.[19] In the present study, the RN had a variable length in the anterior compartment of the arm, ranging from 3.1 cm to 10.5 cm. We noted a mean distance of 6.51 ± 2.08 cm until its bifurcation. Besides, the RN bifurcated at a variable distance from the BEL, above, at, or below its level.

According to Abrams and colleagues, in their cadaveric study, the SBRN became cutaneous at a mean distance of 5.1 cm from the radial styloid process, and, according to Meng and colleagues, it was 8 cm.[20,21] However, in the present study, the length of the SBRN from where it became cutaneous with respect to the radial styloid process was 11.52 ± 4.29 cm, which was greater than that noted by Abrams and colleagues and Meng and colleagues.

Artico and colleagues studied the intramuscular length of the PIN, and they noted a mean length of 3.1 cm.[18] In the present study, the length traversed by the PIN in the supinator muscle ranged from 2.4 cm to 6.5 cm, with a mean length of 4.08 ± 1.17 cm.

Although studies have revealed variable diameters of the RN and its branches in cadaveric and ultrasound-related studies,[15,21] the present study showed 2−3 mm as the diameter, which is similar to that shown in previous studies. However, changes in texture due to formalin fixation are a confounding factor in accurate measurement of nerve diameter.

There are limited studies on the histological evaluation of the RN and its branches. A study carried out by Marx and colleagues showed that the SBRN 2−6 fascicles.[15] Waters & Schwartz, in their anatomical study, noted 1−5 fascicles in the PIN.[22] In the current study, the SBRN had a maximum number of fascicles,[6−13] when compared to the RN[1−7] and the PIN.[2−7] For the axonal count and fascicular and non-fascicular areas, there was no relevant literature to compare. While calculating the fascicular and non-fascicular areas, we noted a larger non-fascicular area in all three nerves examined. In the PIN, the non-fascicular area was significantly larger than the fascicular area. The axons in the RN were unequally divided, and more axons were distributed in the PIN than in the SBRN, although this difference was not statistically significant.

In all the previous studies, the specific parameters of the RN and its branches were studied (as in the cases of its course in the arcade of Frohse or the length of the SBRN from its origin to the radial styloid process).[21,23,24] In our study, we examined the RN course in detail with respect to various anatomical landmarks at possible compression sites, along with the bifurcation level, which could be very useful for conducting more accurate surgical procedures. Moreover, the histology of the RN and its branches analysed in our study may help surgeons when planning the surgical repair of nerve injuries.

## Limitations of the study

Formalin fixation may interfere with nerve diameter, and the measurements may vary between a cadaver and a living person. We could not compare age-related changes in the nerves, as we did not know the exact age of all the cadavers.

## Conclusions

The RN and PIN had more variable morphometry when compared to the SBRN. The RN had a variable level of termination from the BEL. The anatomical landmarks served as a guide for locating the RN and its branches. The PIN had a variable intramuscular length within the supinator muscle. As the supinator and brachioradialis tendon are the most frequent sites of RN branch compression, the morphometry of the RN with respect to these could aid in their surgical exposure for decompression. The SBRN had more fascicles when compared with the RN and PIN. Distribution of the number of axons in the SBRN and PIN did not differ significantly. Our study was unique in its histologic evaluation of these nerves at potential compression sites and could serve as a guide for surgeons planning nerve reconstruction surgery. The histologic evaluation and quantification of the RN could aid surgeons in matching nerve fascicles during grafting surgeries.

## Source of funding

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## Conflict of interest

The authors have no conflict of interest to declare.

## Ethical approval

The Institutional Ethics Committee, Kasturba Medical College, granted ethical clearance (ID: 490/2019).

## Authors contributions

ADS and MH conceptualized the project and planned the methods. SN collected the data, prepared the original draft, digitally analysed the data and tabulated the results. SN, with the guidance of ADS, applied for institutional funding. VHA contributed to the methods and critically reviewed the draft manuscript. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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