

Macroanatomical study on origin and distribution of Caucasian Lynx (*Lynx lynx dinniki*)'s the brachial plexus

Estudio macroanatómico del origen y distribución del plexo braquial del lince caucásico (*Lynx lynx dinniki*)

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ABSTRACT

This study aimed to determine the formation of the plexus brachialis, the nerves that ramify from the plexus, and their last branches in the Caucasian Lynx. It was found that the formation of the brachial plexus contributed to the ventral branches of the C6th, C7th, C8th, and T1th spinal nerves in the lynx. The ventral root of the C6th spinal nerve gave rise to the suprascapular nerve, the ventral of the C6th and C7th spinal nerve to the subscapular nerves and musculocutaneous nerve, the C7th to the cranial pectoral nerve, the C8th to the caudal pectoral nerve, the C8th and T1th to the lateral pectoral nerve, the radial nerve and the ulnar nerve, and the C7th, C8th, and T1th to the median nerve. The network formed by these branches was the origin of the cranial, caudal, long and lateral pectoral nerves, the suprascapular nerve to the extrinsic muscles of the scapula, the subscapular nerve to the intrinsic muscle of the scapula, the axillary nerve to the major teres and caudal portion of the subscapular muscle, the musculocutaneous nerve to the biceps muscle and its cutaneous, the radial nerve to the muscles of the forearm and paw craniolateral aspect, the median nerve to the flexor digitorum superficial and profound muscles, and the ulnar nerve to the flexor ulnar carpi and the flexor deep digitorum muscle.

Key words: Anatomy; brachial plexus; nerves; thoracic limb; caucasian lynx

RESUMEN

Este estudio tuvo como objetivo determinar la formación del plexus brachialis, los nervios que se ramifican del plexo y sus últimas ramificaciones en el Lince del Cáucaso. Se encontró que en la formación del plexo braquial contribuyeron las ramas ventrales de los nervios espinales C6, C7, C8 y T1 en el lince. La raíz ventral del nervio espinal C6 dio origen al nervio supraescapular, la ventral de los nervios espinales C6 y C7 a los nervios subescapulares y al nervio musculocutáneo, el C7 al nervio pectoral craneal, el C8 al nervio pectoral caudal, el C8 y T1 al nervio pectoral lateral, al nervio radial y al nervio ulnar, y el C7, C8 y T1 al nervio mediano. La red formada por estas ramas fue el origen de los nervios pectorales craneal, caudal, largo y lateral, el nervio supraescapular para los músculos extrínsecos de la escápula, el nervio subescapular para el músculo intrínseco de la escápula, el nervio axilar para el músculo redondo mayor y la porción caudal del músculo subescapular, el nervio musculocutáneo para el músculo bíceps y su cutáneo, el nervio radial para los músculos del antebrazo y el aspecto craniolateral de la pata, el nervio mediano para los músculos flexores digitales superficial y profundo, y el nervio ulnar para el músculo flexor ulnar del carpo y el músculo flexor digital profundo.

Palabras clave: Anatomía; plexo braquial; nervios; miembro torácico; lince del cáucaso

INTRODUCTION

The bobcat (*Lynx lynx*) is a wild cat found throughout the world, from the Americas to Europe. It is a medium-sized species with a small head, a pronounced ruff of fur, ears tipped with tufts of black hair, a short tail, and long legs. Bobcats lack a set of upper premolars, distinguishing them from other felids [1].

The brachial plexus, formed by the ventral roots of the cervical C6th, C7th, C8th, and thoracic T1th spinal nerves, is a complex network of nerves, including motor, sensory, and sympathetic fibers, that supplies the structure of the forelimb and thoracic wall in carnivores [2, 3, 4]. Additionally, it has been found that the ventral roots of the C5th [5] and T2th neurons contribute to the network nerve. The nerves that emerge from the brachial plexus are known as the suprascapular, subscapular, axillary, thoracodorsal, lateral and long thoracic, pectoral, musculocutaneous, radial, median, and ulnar [2, 3, 6]. The thoracodorsal, long and lateral thoracic pectoral nerves feed the thoracic wall. In carnivores, the medial and lateral faces on the scapula are supplied by subscapular and suprascapular nerves anchored in the C6th and C7th [2, 3, 4, 6]. The ventral roots of C6th and C7th spinal nerves or the C6th, C7th, and C8th spinal nerves in the carnivores give rise to axillary nerve, which supplies the deltoid, teres major, and minor [4]. The radial nerve which branches from the ventral roots of the C7th, C8th, and T1th spinal nerve, innervates the triceps brachii, anconeus, tensor faciae antebrachii, brachioradialis, and extensor muscles of the forearm [6], whereas the median nerve, which has the same origin as the radial nerve, innervates the pronator teres, pronator quadratus, flexor digitorum superficialis and profundus, and flexor carpi radialis muscles [3, 4, 6]. The ulnar nerve, which is a continuation of the C8th and T1th ventral roots, supplies the flexor carpi ulnaris and deep digital flexor muscles [2, 3, 4, 5, 6, 7].

The forelimbs of cats are used not only for locomotion but also for grappling and subduing prey before killing them [8]. For this reason, the bones [9], muscles [10], and brachial plexus [4, 5, 7] of the forelimbs in the carnivores have been extensively studied. However, because there is no known information on the origin and branching of the brachial plexus in bobcats, this study aimed to characterize the origin and distribution of the brachial plexus by anatomical dissection.

MATERIALS AND METHODS

The anatomic research was conducted on three adult female Anatolian bobcat cadavers with mean weights of 6.9 kg (cadaver I), 7.6 kg (cadaver II), and 9 kg (cadaver III) obtained from the Republic of Türkiye Ministry of Forest and Water Works Sivas Branch Manager. The common carotid artery of the bobcats was initially inserted with a plastic cannula, and for fixation, we administered a

10% formaldehyde solution to the arterial system of the cadavers via the cannula (Ayset IV. Cannula 20G-11×32mm Türkiye). The skin and muscles that link the forelimb to the body were then removed, revealing the brachial plexus and its nerves. We measured the brachial plexus and its nerves using a digital caliper (Carbon Fiber Composites Digital Caliper Chengdu Ditron Tools Co. Ltd PRC) and photographed them with an iPhone 12 PROMAX®. The nomenclature used in this study was adopted by Nomina Anatomica Veterinarians [11].

RESULTS AND DISCUSSIONS

In three bobcat cadavers, the brachial plexus was formed by the ventral roots of the sixth (C6th), seventh (C7th), and eighth cervical (C8th) spinal nerves and the first thoracic (T1th) nerve, between longus colli and scaleni muscles (FIG. 1).

According to current literature, several studies have been conducted on the formation of the plexus brachialis, the nerves ramifying from the plexus, the nerves ramifying from the plexus and their branches, and the final result in many mammal species and races. Research has shown that the ventral roots of the C6th, C7th, C8, and T1th spinal nerves form the plexus in cats [12, 13], Turkish Van cats [4], and dogs [7, 14]. The ventral roots of the C5th and T2th branches, which were found to form the plexus in cats [12, 15] and Giant Anteaters [5] did not form the plexus in bobcats [3, 4, 5, 13, 14, 16, 17].



FIGURA 1. Origin of brachial plexus. C: ventral branch of cervical spinal nerve T: ventral branch of thoracic spinal nerve

The plexus was shown to be the origin of the subscapular (FIGS. 2a–c), thoracodorsal (FIG. 2 [7]), suprascapular (FIG. 2 [1]), axillary (FIG. 2 [3]), musculocutaneous (FIG. 2 [4]), radial (FIG. 2 [8]), ulnar (FIG. 2 [9]), and median (FIG. 2 [10]) nerves in every cadaver.

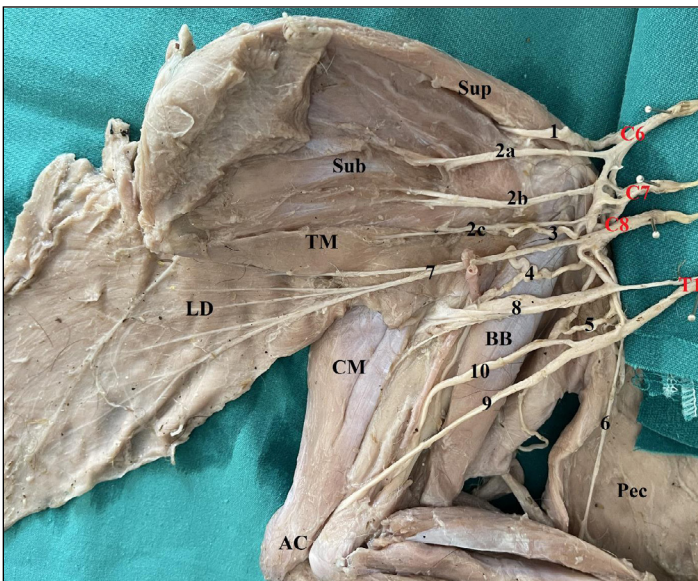


FIGURA 2. Nerves forming plexus brachialis. 1: *n. suprascapularis*, 2a: *cranial part of the nn. subscapularis*, 2b: *middle part of the nn. Subscapularis*, 2c: *caudal part of the nn. Subscapularis*, 3: *n. axillaris*, 4: *n. musculocutaneus*, 5: *n. pectoralis cranialis*, 6: *n. pectoralis caudalis*, 7: *n. thoracodorsalis*, 8: *n. radialis*, 9: *n. ulnaris*, 10: *n. medianus* C6: Ventral branch of the 6th cervical spinal nerve, C7: Ventral branch of the 7th cervical spinal nerve, C8: Ventral branch of the 8th cervical spinal nerve, T1: Ventral branch of the 1st thoracic spinal nerve. Sup: *musculus suprascapularis*, Sub: *musculus subscapularis*, TM: *musculus teres major*, LD: *musculus latissimus dorsi*, CM: *Medial head of triceps brachii muscle*, BB: *musculus biceps brachii*, AC: *articulatio cubiti*, Pec: *musculus pectoralis ascendens*

The suprascapular nerve (FIG. 2 [1]) originates from the ventral roots of C6th in three cadavers on both the left and right sides. The nerve continued laterally to the suprascapular muscle, passing between it and the subscapular muscle around 4 cm from the humeroglenoid joint.

According to previous research [4, 12, 13, 15], the suprascapular nerve originates from the ventral roots of the C6th spinal nerve in bobcat cadavers. Contrary to what Dyce et al. [2] observed in cats, it was found that the ventral branch of the C7th spinal nerve does not contribute to this nerve.

The subscapular nerves, which have three roots (cranial, middle, and caudal; FIGS. 2a–c), arise the ventral roots of C6th and C7th between the scalene and longus colli muscles. The cranial branch (FIG. 2a) emerged as the ventral branch of the C6th spinal nerve, whereas the middle (FIG. 2b) and caudal roots (FIG. 2c) ramified from the ventral branch of the C7th. After origin, the cranial branch distally leads to the suprascapular and middle branches of the subscapular nerve, terminating the cranial portion of the subscapular muscle at the middle one-third level (FIG. 2a). It was observed that the middle branch was thicker than the cranial and caudal roots and split from the ventral roots of both the C6th and C7th (FIG. 2b).

The branch continues distally until it reaches the middle part of the subscapular muscle (FIG. 2b). The caudal branch of the subscapular nerves, which originates from the ventral branch of C7th, continues distally and gives rise to a thin branch for the caudal portion of the subscapular muscle at the level of the distal one-third (FIG. 2c). The main branch then leads directly to the teres major muscle, where it ramifies (FIG. 2).

According to previous research [4, 12, 13, 15], the suprascapular nerve originates from the ventral roots of the C6th spinal nerve in bobcat cadavers. Contrary to what Dyce et al. [2] observed in cats, it was found that the ventral branch of the C7th spinal nerve does not contribute to this nerve.

The study found that the subscapular nerves originate from the ventral roots of the C6th and C7th spinal nerves as cranial, medial, and caudal roots, as stated in the literature [12, 13, 15, 16]. The innervation area and branching of this nerve were identical to those found in the Turkish Van cat [4]. However, it was shown that the caudal branches of the nerve innervated the teres minor muscle in the study.

In all cadavers, the axillary nerve bifurcates from the ventral roots of C6th and C7th and travels to the caudal portion of the glenohumeral joint (FIG. 2 [3]). At this level, the nerve that connects the caudal portion of the subscapular and teres major muscles bends to the lateral surface of the scapula (FIG. 2 [3]).

The thoracodorsal nerve originates from the ventral branch of C8th and travels dorsocaudally parallel to the caudal side of the teres major muscle before branching on the medial surface of the thoracodorsal muscle (FIG. 2).

The musculocutaneous nerve bifurcates from the connecting branch produced by the ventral roots of the C6th and C7th spinal nerves and travels distally to reach the caudal side of the biceps brachii muscle (FIG. 2 [4]). At the distal end of the shoulder joint, after giving rise to a muscular branch for the one-third proximal part of the biceps brachii muscle, the nerve continues distally between the caudal side of the biceps brachii muscle and the medial aspect of the humerus (FIG. 3). The musculocutaneous nerve bends laterally at one-third the distance from the humerus and terminates on the medial surface of the brachial muscle (FIG. 3).

According to literature [4, 12, 13, 15, 16], the axillary and musculocutaneous nerves originated from the ventral roots of the C6th and C7th spinal nerves in bobcats. According to studies [4, 5, 12, 13, 15, 16], the axillary nerve innervates the muscles on the lateral side of the axillary shoulder joint, whereas the musculocutaneous innervates the muscles on the medial part of the arm in all bobcat cadavers.



FIGURA 3. Course and distribution of the musculocutaneous nerve. **H:** humerus, **BB:** musculus biceps brachii, **Asterices:** Branches of the musculocutaneous nerve.

The cranial pectoral nerve, which originates from the ventral branch of the C⁷ spinal nerve, passes cranioventrally under the transverse pectoral muscle and 3 cm lateral to the median line to reach it. In each of the six cases, the nerve end divides the transversal and superficial pectoral muscles into three branches (FİGS. 2 and 4).

Previous studies [4, 5, 12, 13, 15, 16] have shown that the ventral branch of the C⁷th spinal nerve is where the cranial and long pectoral nerves originate. The cranial pectoral nerves were found to be placed on the superficial pectoral muscle, whereas the long pectoral nerve innervated the serratus ventralis thoracic muscle, as shown by Nur et al. [4] in the Turkish Van cat.

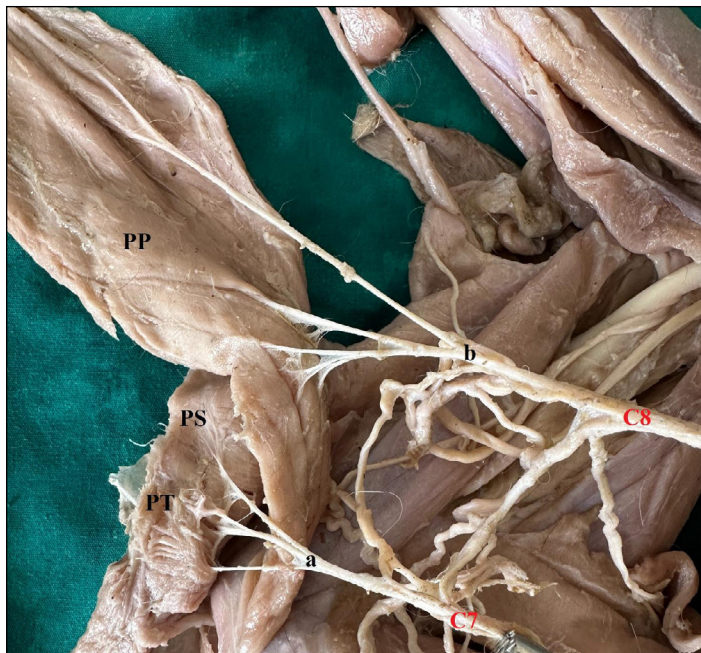


FIGURA 4. Origin of cranial and caudal pectoral nerve and distribution in related muscles. **C7:** Ventral branch of the seventh cervical spinal nerve, **C8:** Ventral branch of the eighth cervical spinal nerve, **a:** nervus pectoralis cranialis, **b:** nervus pectoralis caudalis, **PT:** musculus pectoralis transversus, **PS:** musculus pectoralis superficialis, **PP:** musculus pectoralis profundus

The caudal pectoral nerve, which originates from the ventral branch of the C⁸th spinal nerve, runs along

the medial surface of the profound pectoral muscle at a distance of 2 cm from the humeral medial condyle. The nerve eventually bifurcates into three branches on the profound pectoral muscle (FİG. 4).

This study confirms previous findings [3, 5, 12, 13, 15, 16] that the caudal pectoral nerves and the lateral pectoral nerve originate from the ventral branch of the C⁸th spinal nerve in the bobcat. According to Turkish Van cat [4], the ventral branch of the T¹th spinal nerve in the bobcat contributes to lateral pectoral nerve formation as well. According to literature [4, 5, 12, 13, 15, 16], the nerves end the profound pectoral muscle in the bobcat.

In all three cadavers, the lateral thoracic nerve originates from the ventral branch of C⁸ and T¹ and ends up ramifying on the medial surface of the caudal half of the profound pectoral muscle.

The radial nerve was formed by a thin branch from the ventral branch of the T¹ spinal nerve and a thick branch from the ventral branch of the C⁸ spinal nerve (FİG. 2 [8]). Both roots merged at an average distance of 3 mm from the origin, forming the thickest nerve of the brachial plexus (FİG. 2 [8]). In the three cadavers, the nerve running cranioventrally gives off a thin branch for the medial caput of the triceps brachii, and the main nerve reaches the trigonum area between the insertio of the teres major muscle, the origin of the caput mediale, and the caput longum of the triceps brachii (FİG. 2 [8]). After the radial nerve provides muscle branches close to the middle of the humerus, the nerve curves from medial to lateral ends and divides into deep and superficial branches at the distal to third of the humerus. The deep branch was shown to continue distally until it reached the forearm extensor muscles. The superficial branch runs distally along the caudal face to the cranial face of the elbow joint. The nerve then traveled distally with the cephalic vein on the cranial face of the forearm to the craniodorsal face of the hand-wrist joint (FİG. 5A). At this level, the branch was divided into three branches: medial, middle, and lateral, with the branches occupying the area between the first and second fingers, the second and third fingers, and the third and fourth fingers on the dorsal surface of paw, respectively (FİG. 5B).

Contrary to the origin of the radial and thoracodorsal nerves in the literature [3, 4, 5, 12, 13, 14, 15, 16, 17], it was found that the radial nerve and thoracodorsal nerve originate from the ventral roots of the C⁸th and T¹th spinal nerves in this all specimens. The axillary nerve was found to innervate the medial part of the triceps brachial muscle in the bobcat, then reach the lateral surface of the arm where the superficial and deep branches, which is consistent with the findings reported by literature [3, 4, 5, 14, 17].

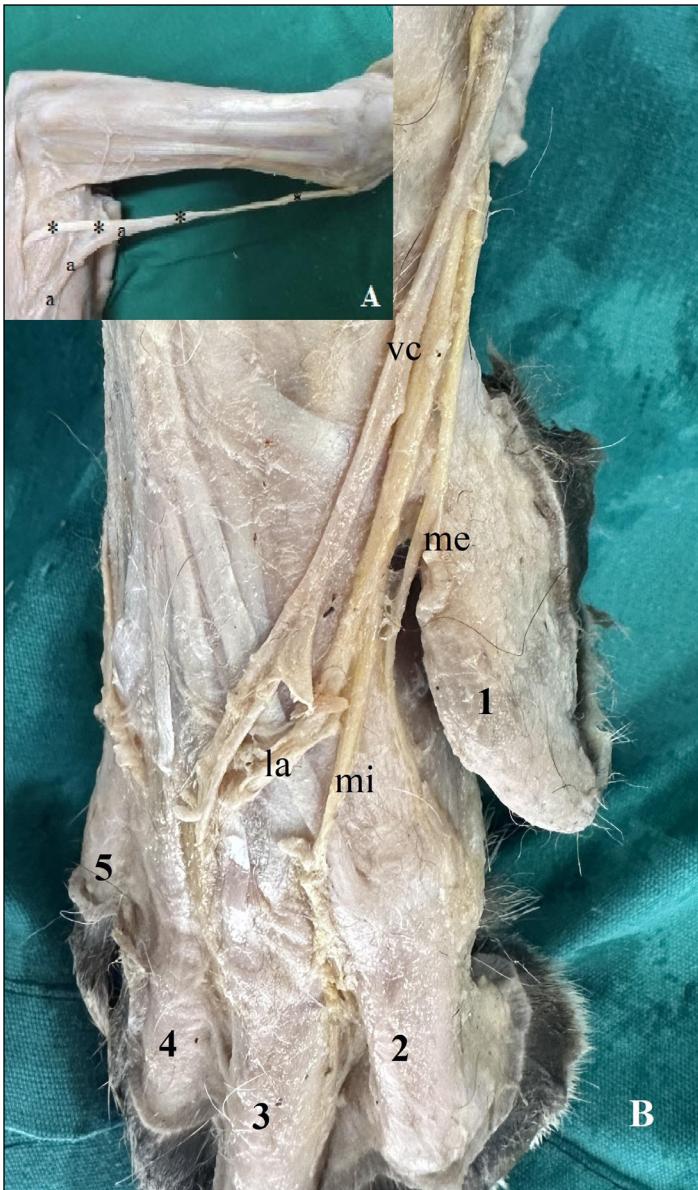


FIGURA 5. A: Course of the superficial branch of the radial nerve. Asterisks: *N. radialis*, a: *vena cephalica*. B: Course of the terminal branches of the radial nerve. 1: first finger, 2: second finger, 3: third finger, 4: fourth finger, 5: fifth finger, vc: *vena cephalica*, me: branch of the *radialis* nerve distributed between the 1st and 2nd fingers, mi: branch of the *radialis* nerve distributed between the 2st and 3rd fingers, la: branch of the *radialis* nerve distributed between the 3st and 4nd fingers

The median nerve, formed by the ventral roots of the C7th, C8th, and T1th spinal nerves, runs distally between the cranial side of the humerus and the biceps brachii muscle on the medial surface of the humerus, passing through the supracondylar foramen to reach the proximal part of the forearm (FIGS. 2 and 6). The nerve was shown to travel distally between the supinator and the flexor digitorum superficial muscle, followed by the flexor digitorum superficial and profound muscle of the caudal surface of the forearm. After giving branches to the last two muscles in this region, it was observed that the nerve traveled distally under the flexor digitorum muscle to reach the

distal one-third of the forearm. The median nerve, which runs along the median side of the tendons of the flexor digitorum superficial and profound muscles on the palmar aspect of the carpal joints, was divided into three roots at the palmar aspect of the fingers in the three cadavers.

As depicted by literature [3, 4, 5, 12, 13, 14, 15, 16, 17], the median nerve is formed by the ventral roots of the last two cervical and T1th spinal nerves in this study. The nerve was found to innervate the supinator and flexor muscles on the caudal surface of the forearm, with the nerve ends dividing to the last branches on the palmar surface of a pawn in a bobcat. The results of this study were consistent with those of domestic cats [3,4, 5, 14, 17].

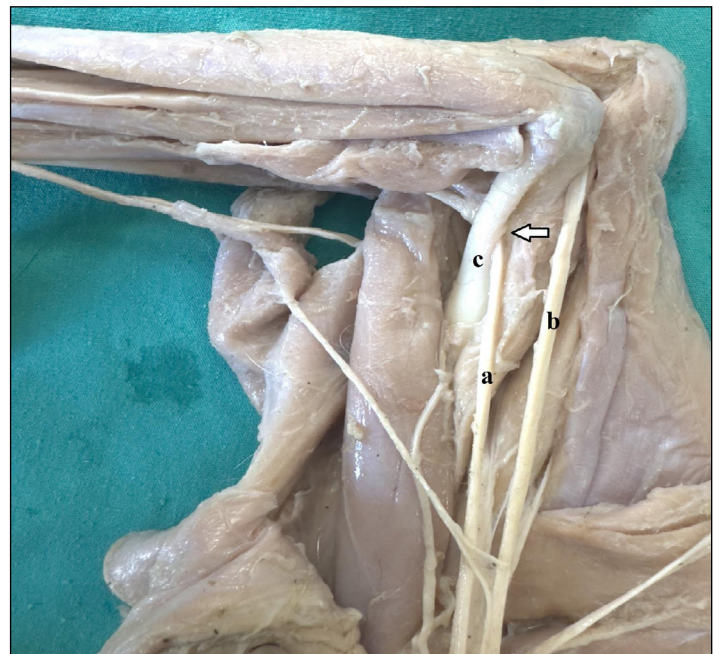


FIGURA 6. Course of the median nerve between the musculus biceps brachii and the humerus. Arrow: *foramen supracondylare*, a: *nervus medianus*, b: *nervus ulnaris*, c: *humerus*

The ulnar nerve, formed by the ventral roots of C8th and T1th, traveled caudally on the medial surface of the brachium until it reached the medial surface of the elbow joint, passing between the medial surface of the olecranon and the medial condyle of the humerus (FIG. 2). It was observed that the nerve running distally between the flexor ulnar carpi and the flexor digitorum profund muscle reached the level of the carpal pad. During its course, the ulnar nerve sends a slender branch to the dorsal part of the carpal joint.

Researchers found that the ventral roots of C8th and T1th spinal nerves connect to the ulnar nerve [3, 4, 5, 12, 13, 14, 15, 16, 17].

CONCLUSIONS

In conclusion, it was found that the plexus brachialis was formed by the ventral roots of the C6th, C7th, C8th,

and T1th spinal nerves; however, the network formation did not contribute to the ventral roots of C5th and T2th spinal nerves. In all cadavers used in this study, it was found that the suprascapular nerve for the lateral aspect of the scapula originated from the ventral root of the C6th spinal nerve; the subscapular nerve for the medial surface of the scapula, the musculocutaneous nerve for the biceps muscle arose from the ventral root of the C6th and C7th; the cranial pectoral nerve separated from the ventral root of the C7th; the caudal pectoral and the thoracodorsal nerve were from ventral root of the C8th; the lateral pectoral nerve, the radial nerve and the ulnar nerve derived from the ventral root of C8th and T1th spinal nerve; and the ventral roots of the C7th, C8th, and T1 gave rise to the median nerve. The median nerve was found to innervate the flexor muscles of the finger, namely, the flexor digitorum superficial and profound muscles in the bobcat. Furthermore, in this study, it was shown that the ulnar nerve stimulated the muscles in the forearm and paw.

Conflict of Interest Statement

The authors have no conflict of interest to declare.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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