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ORIGIN AND DISTRIBUTION OF BRACHIAL PLEXUS OF WHITE NEW ZEALAND RABBIT (*Oryctolagus cuniculus*)

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Abstract. The study was conducted to know the anatomy of the brachial plexus of White New Zealand Rabbit (*Oryctolagus cuniculus*). Ten healthy male and female White New Zealand rabbits were dissected in this study. It was found that the brachial plexus of the White New Zealand Rabbit was formed by ventral branches of C5, C6, C7, C8, T1 and T2 spinal nerves. The cranial trunk was formed by the caudal branch of C5, C6 and caudal trunk formed by rami ventralis of C7, C8, T1 and the cranial branch of ventral ramus of T2. Cranial pectoral nerve originated from the caudal trunk spreading into the pectoral muscles. The musculocutaneous nerve innervates into the brachial muscle and the axillary nerve into the subscapular muscle. The radial nerve was divided into two branches as ramus profundus and ramus superficial then divided into the digital dorsal common III and IV. The thoracodorsal nerve innervates the latissimusdorsi muscle. The median nerve was divided into digital dorsal common I, II, III and IV nerves. The ulnar nerve formed the caudal cutaneous antebrachial then digital dorsal common IV and V nerves. Lateral thoracic and caudal pectoral nerves originated from the caudal trunk. The origin and distribution of brachial plexus resemble that of porcupines but differ from other mammals.

Keywords: White New Zealand rabbit, brachial plexus, forelimb

INTRODUCTION

Livestock is one of the major economic resources of Bangladesh. Micro-livestock like rabbit may be considered an emerging sector for growth of the economy, in addition to other protein supplements from animal sources such as poultry. Use of laboratory animals like rabbits, rats and guinea pigs is increasing day by day for experimental purposes. Rabbits are raised for several purposes including

meat and fur production, as laboratory animals, for show purposes and as pets (1). Rabbit meat is acknowledged as high quality lean meat, being high in protein but low in fat and cholesterol (2, 3). The promising future demand of this animal warrants investigations into the different morphological systems of the rabbit for its use in clinical, surgical and research fields. Microsurgical techniques have largely improved the treatment of lesions in the peripheral nerve and brachial plexus. Other experimental work is limited. The rabbit model offers advantages, including rapid regeneration for a fairly short observation period (4). Special attention has been given to the dissection or neurological study of the different organs or regions of the body, because of variations among animal species. Some authors have studied the formation of nerve plexuses in domestic animals which showed that its organization varies. [The brachial plexus has been studied in mammals such as dogs (5, 6, 7, 8) and cats (5, 9, 10).] Rabbits have been used as an experimental model in diseases, such as peripheral nerve injury and brachial plexus injury. However, some aspects of their macro-anatomy need a more detailed description. The brachial plexus has been studied in mammals such as dogs (5, 6, 7, 8), cats (5, 9, 10), vervet monkeys (11), chacma baboons (12), mice (13, 14), rats (15, 16), porcupines (17) and rabbits (10, 18, 19). The White New Zealand Rabbits (*Oryctolagus cuniculus*) are from the order Lagomorpha. The aim of this present study was to make a detailed investigation of the origin and distribution of nerves arising from the brachial plexus in White New Zealand Rabbits to give support for experimental research for the clinical, radiological and surgical practice of this animal.

MATERIALS AND METHODS

Statement of the experiment

The experiment is an *in situ* study of the origin and distribution of the brachial plexus of the White New Zealand Rabbit (*Oryctolagus cuniculus*), carried out in the laboratory of the Department of Anatomy and Histology, Chittagong Veterinary and Animal Sciences University, Chittagong, Bangladesh. The duration of study was about two months.

Experimental animals

The study population was ten adult clinically healthy male and female White New Zealand Rabbits at 7 days old which were purchased from the local market in the Chittagong Metropolitan area. During purchasing, sexing of the rabbit was by observing the vent region. Before being used in the experiment, they were kept for 15 days to acclimatize them to the environment.

Rearing and care

The rabbits were cared for at the Animal Care Room, Department of Anatomy and

Histology, Chittagong Veterinary and Animal Sciences University, Chittagong, Bangladesh, in proper hygienic conditions, with normal feed of green grass, leaf, different types of grains and water *ad libitum*. The ventilation of the rearing house of Rabbit was sufficient as a standard one.

Selection and Identification of White New Zealand Rabbit

White New Zealand Rabbit is becoming very popular as a pet animal in the country. Its availability in the local markets of Bangladesh makes it an important animal to investigate its anatomical significance. It is also widely used as a laboratory animal due to its short gestational length (30-32 days) and easy handling. White New Zealand rabbit is pure white in color with long erected ears.

Laboratory preparation

Required reagents

28 70% Alcohol and diazepam (Sedil®)

Required instruments and appliances

Syringe with needle, tissue forceps, rat-toothed forceps, Allis forceps, scalpel with handle, cotton, gauze, gloves and thread

Anesthesia and killing of Rabbit

The animals were killed according to the Ethics of Animal Research Committee of the institution. First, the rabbit was weighed using a weighing balance. Then, it was stretched out with the help of strings tied to the table at ventro-dorsal position. In order to kill, an overdose of Sedil® (diazepam at 10 mg/kg body weight) was introduced into the external jugular vein.

Dissection of the fore limb of Rabbit

The rabbit was kept in lateral recumbency after it was killed. The spinal nerves forming the brachial plexus with its branches was dissected out carefully. During dissection, the skin, fascia and adipose tissues covering the shoulder were removed carefully with the help of tissue forceps, rat-toothed forceps, Allis forceps and scalpel with a handle. The courses of the nerves emanating from the plexus were exposed. The muscles and tendons were dissected and reflected whenever necessary to trace the course of the nerves. The brachial plexus in both forelimbs were examined and photographed by using a 12 megapixel digital camera with 4× zoom (Sony®). See Figures 1, 2, 3, 4, 5. The organization of the main branches of the brachial plexuses of ten adult rabbits irrespective of sex was investigated. Observations were performed on the non-fixed material, immediately after killing the animals to draw the results.

Identification of the nerves

Nerves of the brachial plexus were identified according to the innervation

in muscles of the neck, arm, forearm and thorax.

Nomenclature of the nerves

For the terminologies, the Nomina Anatomica Veterinaria (20) was used. The results obtained were compared, with the results from other studies of dogs (5-8), cats (9, 6, 10), Vervet monkeys (11), Chacma baboons (12), mice (13), rats (15, 16) and porcupines (17).

RESULTS

The brachial plexus of the rabbit emerged between the dorsal scalenus and the ventral sclaneus muscle, just proximal to the first rib and medial aspect of the scapula. It constituted of the ventral branches of C5, C6, C7, C8, T1 and T2 spinal nerves. The ventral rami of C5 spinal nerve and T2 spinal nerve were divided into two branches. It also contributed to the caudal branch of ramus ventralis of C5 spinal nerve and the cranial branch of ramus ventralis of T2 spinal nerve. The cranial branch of ramus ventralis of C5 spinal nerve and the ramus ventralis of C6 spinal nerve formed the cranial trunk and cranial branch of T2 spinal nerve and rami ventralis of C7, C8 and T1 spinal nerves formed the caudal trunk which was the largest trunk. Two branches originating from the cranial trunk were bound to the cranial part of the caudal trunk (Figure 1).

Origin of different nerves of the brachial plexus

Long thoracic nerve

Before joining to the brachial plexus, the ventral branches of C6 and C7 spinal nerves, as each of C6 and C7 spinal nerves divided into two thin branches, passed beneath the scalenus dorsalis muscle and at the first rib, then turned to the caudal and dispersed into serratus ventralis thoracic muscle.

Nerves originated from cranial trunk

Phrenic nerve, supra scapular nerve, the first branch of subscapular nerve and a branch bound to the caudal trunk were originated from the cranial trunk of the brachial plexus (Figure 1).

Nerves originated from caudal trunk

Cranial pectoral nerve, axillary nerve, the second branch of subscapular nerve along with axillary nerve, thoracodorsal nerve, musculocutaneous nerve, radial nerve, ulnar nerve, median nerve, lateral thoracic nerve and caudal pectoral nerve were originated from caudal trunk of brachial plexus of rabbits (Figure 1).

In rabbit, was found that the plexus brachialis was formed by two trunks, called cranial and caudal from which the nerves that spread through forelimbs originated.

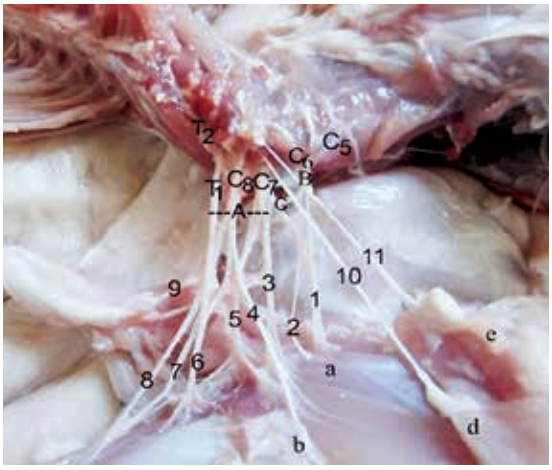

Figure 1. Lateral view of the brachial plexus in the rabbit. C5 – Caudal branch of ramus ventrali of C5, C6 – Ramus ventralis of C6, C7 – Ramus ventralis of C7, C8 – Ramus ventralis of C8, T1 – Ramus ventralis of T1, T2 – Cranial branch of ramus ventralis of T2; 1–Suprascapular nerve, 2 – Subscapular nerve, 3 – Axillary nerve, 4 – Thoracodorsal nerve, 5 – Musculo cutaneous nerve, 6 – Radial nerve, 7 – Median nerve, 8 -Ulnar nerve, 9 – lateral thoracic nerve, 10 – Cranial pectoral nerve, 11- Caudal pectoral nerve; a – Subscapular muscle, b –Latissimus dorsi muscle, d-Pectoralis ascendens muscle, e- Pectoralis descendens muscle.

Figure 2. Branches of median nerve at the palmer part of metacarpus.

Figure 3. Separation of median nerve from musculocutaneous nerve at the level of distal end of humerus.

Figure 4. Digital dorsal and palmar nerve V (branches of the ulnar nerve) supplies the skin and subcutaneous tissues of the sole.

Figure 5. Caudal cutaneous antebrachial nerve (branch of the ulnar nerve) at the level of cubital joint.

Distribution of nerves emerging from the brachial plexus

The supra scapular nerve originated from cranial part of cranial trunk, passed between subscapular muscle and supraspinatus muscle at collum scapula level, existed at lateral face of scapula and continued through supraspinatus muscle and infra spinatus muscle.

The subscapular nerve was two nerves. The first one originated from the cranial trunk which spread through the subscapular muscle. The second one originated from the caudal trunk with axillary nerve and dispersed to the caudal part of subscapular muscle and teres major muscle after leaving the axillary nerve.

The axillary nerve originated from the point that the branch coming from cranial trunk then joined the caudal trunk and after a short distance, became divided into two branches. First branch was given to the subscapularis and teres major muscles. This nerve at the level of collum scapula at the caudal of scapula coursed between teres major and supra scapular muscles to the lateral face of the scapula. After giving branches to teres minor and deltoid muscles, it passed to the lateral face of the forelimb through the space between caput lateralis of triceps brachii muscle and deltoid muscle and gave the cutaneous brachii lateralis cranialis which spread to the cranial of lateral of forelimb and then continued as the cranial cutaneous antebrachii nerve.

The thoracodorsal nerve arose from caudal trunk becoming two branches: the axillary nerve and radial nerve which spread through latissimus dorsi muscle.

The radial nerve originated from the medial part of caudal trunk together with median nerve and ulnar nerve. At midway down the humerus, it passed between capus medialis and capus lateralis of the triceps brachial muscle to the lateral face of the arm and gave rami musculares to tensor fascia antebrachii muscle and triceps brachii muscle. First, it gave lateral cutaneous antebrachii nerve between brachii muscle and caput lateralis of triceps brachii muscle and then divided into two branches called ramus profundus and ramus superficialis. Ramus profundus distributes through extensor muscles on antebrachium. Ramus superficialis separated into the digital dorsal common III and IV nerves on distal of antebrachium, descending on extensor carpi radial muscle.

The median nerve was the longest nerve of the brachial plexus originating from the caudal trunk in common with the ulnar and musculocutaneous nerves as a common root. After leaving the caudal trunk, firstly as the ulnar nerve and then near to the distal of the humerus, it separated as the musculocutaneous nerve (Figure 2). The median nerve did not give any branch until the articulation cubiti level where it gave two branches called rami muscularis and interosseus antebrachial nerve on antebrachium. Then it ended as four branches; digital dorsal common I, II,

III and IV nerves, at the central level of the palmar part of the metacarpus (Figure 2).

Ulnar nerve originated from caudal trunk together with median and musculocutaneous nerves and then separated from them. It gave the caudal cutaneous antebrachii nerve at the caudal of antebrachium and rami muscularis at the level of cubital joint (Figure 5). The nerve divided in to digital dorsal and palmar nerve V (Figure 2) at caudomedial of antebrachium. Prior to spreading to the palmar and dorsal of the digiti V one branch originated from each of them spreaded to the skin and subcutaneous tissues of sole.

Cranial pectoral nerve had four branches, two spreading to pectoral descendens muscle, one to pectoral descendens muscle and pectoral transverses muscle, one together with lateral thoracic nerve and caudal pectoral nerve to cranial part of pectoral transversus muscle and pectoral ascendens muscle. Lateral thoracic nerve originated from caudal trunk and passed through pectoral ascendens muscle. After giving a branch to cranial part of this muscle, it spread into the cutaneous omobrochial muscle. Caudal pectoral nerve originated from caudal tnunk with lateral thoracic nerve, and gave two branches which spread to lower part of cutaneous trunci muscle and caudal part of pectoral ascendens muscle. Musculocutaneous nerve initially coursed through the distal of the humerus together with the median nerve and then separated from each other. This nerve at level of articulation cubiti, became the ramus muscularis distalis to the brachial muscle and centre of antebrachium, medial cutaneous antebrachii (going through skin fascia), and the other branch divided into the digital dorsal common I and II nerves at the level of the phalanx proxima.

DISCUSSION

It has been reported that the formation of the brachial plexus varies in some species. The brachial plexus of rat is formed by contribution of ventral rami of C5, C6, C7, C8, T1 and T2 spinal nerves (15, 21). However, (4) reported that ventral branches of T2 spinal nerve are not involved. Another study was undertaken by (17) which revealed that the brachial plexus of porcupine is formed by ventral branches of C5, C6, C7, C8, T1 and T2 spinal nerves. (14) and (13) reported that the brachial plexus is formed by ventral branches of C5, C6, C7, C8 and T1 spinal nerves in mouse. (11) and (12) reported that, brachial plexus of Vervet monkey and Chacma baboon is formed by the ventral branches of C5, C6, C7, C8, T1 and T2 spinal nerves. In the cat, the contribution of the formation of brachial plexus is the ventral branches of C6, C7, C8 and T1 spinal nerves (6, 9). (7) reported that dog brachial plexus is formed by ventral branches of C6, C7, C8, T1 and T2 spinal nerves, while (5, 6) reported that T2 spinal nerve is involved occasionally. The brachial plexus of rabbit is formed by the contribution of ventral branches of C5, C6, C7, C8, T1 and T2 spinal nerves and its formation resembles that of rat

(15, 21), porcupine (17), Vervet monkey (11), Chacma baboon (12) and differs from that of rat (21), mouse (14, 13), cat (6, 9) and dog (6, 5, 7, 8). The ventral branches of C5 spinal nerve and T2 spinal nerve divided into caudal and cranial branches (17). The caudal branch of C5 spinal nerve and cranial branches of T2 spinal nerve contribute to form the brachial plexus in porcupine (17) to which the result of the present study is parallel. The brachial plexus of rabbit consisted of caudal and cranial trunks as that of porcupine (17) and in this respect it differs from those of rat (4, 12) which is formed from caudal, medial and cranial trunks. As in Vervet monkey (11), Chacma baboon (12) and cat (6) the ventral branches of C6 and C7 spinal nerves in porcupines gives a branch to form the long thoracic nerve before they contribute to the brachial plexus. This is different from the finding reported in dogs (7, 8) in which the nerve was originated from the ventral branches of C7 and C8 spinal nerves following the formation of plexus. Brachial plexus of rabbit form a network which resembled the rat (16), mouse (14, 13) and other mammals. Brachial plexus of rabbit consist of two trunks as cranial and caudal which were formed by ventral branches of C5, C6, C7, 13C8, T1 and T2 spinal nerves in rabbit, similar to porcupine (17) and differs from those of rat 14(16) and Chacma baboon (12) which are formed from caudal, medial and cranial trunks.

Emanating nerves from the brachial plexus in rabbit disseminates in different muscles of the forearm is somewhat similar to porcupine (17) and in rat (4), but different from other mammals. In rabbit, nerves from the brachial plexus innervating the coraco-brachial muscle and brachial biceps muscle originated directly from the plexus, and transversely joined the musculocutaneous nerve after giving a branch to each muscle. After giving ramus musculer distalis to brachial muscle and cutaneous antebrachii medial nerve to the medial aspect of antebrachii, musculocutaneus nerve, continued and together with ramus superficialis of radial nerve and dorsal branch of ulnar nerve spread to the dorsal of fingers and palmar branch of ulnar nerve and the last parts of median nerve which supplied the palmar aspect of fingers. (6) Stated that, the musculo-cutaneous nerve in dog passes between the coraco-brachialis and the brachial artery and descends in the arm in front of the artery. At the shoulder joint it gives off branches to the biceps and coraco-brachialis, and in the distal third of the arm is connected with the median nerve by an oblique branch. It terminates near the elbow by dividing into a branch for the brachialis and a small cutaneous nerve which passes down over the medial face of the elbow and, inclining a little forward, descends over the deep fascia of the forearm to the carpus. Whereas (6) stated that, the musculo-cutaneous nerve in horse arises from the anterior part of the plexus and descends over the lateral face of the brachial artery, below which it is connected by a large but short branch

with the median nerve, thus forming a loop in which the artery lies. One or two branches to the pectoral muscles are given off from the nerve or the loop. In rabbit there is a smaller difference in this course with dog (6); where the musculocutaneous nerve initially coursed through distal of humerus together with median nerve and then separated from each other. This nerve at level of articulation cubiti, gave ramus muscularis distalis to brachial muscle and center of antebrachium, medial cutaneous antebrachii (going through skin fascia), other branch divided digital dorsal common I and II nerves at level of phalanx proximal. (6) Stated that, the radial nerve in dog descends behind the ulnar nerve, gives branches to the extensors of the elbow, dips in between the medial head of the triceps accessory head of the anconeus, winds around the arm, and divides between the brachialis and the lateral head of the triceps into two branches. The deep branch supplies the extensor and supinator muscles on the forearm. The superficial branch emerges upon the flexor surface of the elbow and divides into two branches which terminate by supplying two dorsal digital nerves to each digit, except the fifth, which receives its lateral dorsal nerve from the ulnar. The medial branch descends along the medial side of the cephalic vein to the carpus, where it divides into dorsal nerves for the first digit and the medial side of the second. The lateral branch is much larger. It descends on the middle of the front of the forearm and supplies the remaining dorsal digital nerves except that to the lateral side of the fifth digit. In rabbit radial nerve originated from the medial part of caudal trunk together with median nerve and ulnar nerve. At midway down the humerus, it passed between carpus medialis and carpus lateralis of triceps brachial muscle to the lateral face of arm and gave rami musculares to tensor fascia antebrachii muscle and triceps brachii muscle. First, it gave lateral cutaneous antebrachii nerve between brachii muscle and caput lateralis of triceps brachii muscle and then divided into two branches called ramus profundus and ramus superficialis. Ramus profundus distributes through extensor muscles on antebrachium. Ramus superficialis separated digital dorsal common III and IV nerves on the distal of antebrachium, descending on extensor carpi radial muscle. But there is a similarity in the pathway of radial nerve in different muscles in ox and horse (6). The radial nerve in ox is continued below the elbow by a large cutaneous branch. Dorsal cutaneous antebrachial nerve which emerges at the lower border of the lateral head of the triceps and descends on the dorsal aspect of the limb. It communicates above the carpus with the lateral cutaneous branch of the median nerve and terminates in three dorsal digital nerves; two of these descend along the axial or interdigital side of the dorsal surface of the chief digits, and the third along the medial (abaxial) side of the medial chief digit. (6) Stated that, the radial nerve in horse arises from the posterior part of the plexus and is sometimes the largest branch. It descends

with the ulnar nerve over the medial face of the origin of the subscapular artery and the lower part of the teres major and dips into the interstice between that muscle and the long and medial heads of the triceps. (6) Stated that the ulnar nerve in dog is as large as or larger than the median, with which it is united for some distance. At the distal third of the arm it separates from the median and passes over the medial epicondyle of the humerus. At the proximal part of the forearm it gives off the dorsal branch, which supplies cutaneous twigs to the dorso-lateral surface of the distal part of the forearm and carpus and terminates as the lateral dorsal digital nerve of the fifth digit. Descending under cover of the flexor carpi ulnaris, the ulnar inclines medially under the tendon of insertion of that muscle and divide into superficial and deep branches. The superficial branch descends along the lateral border of the flexor tendons, gives off the lateral volar digital nerve of the fifth digit and a branch which descends in the space between the fourth and fifth metacarpal bones and unites with the deep branch. The deep branch descends in the carpal canal and divides under the deep flexor tendon into its terminal branches. The smaller of these supply the volar metacarpal muscles. The larger terminals are the three volar common digital nerves, which descend along the second, third, and fourth intermetacarpal spaces, subdivide, and concur with the volar metacarpal branches of the median nerve in forming the volar proper digital nerves. In horse, the thickness, size of the nerve is different from that of dog. (6) stated that the ulnar nerve in horse arises with the median by a short common trunk. It descends behind the brachial artery and is accompanied a short distance by the radial nerve, from which it can be distinguished by its smaller size. (6) Stated that, the ulnar nerve in ox divides at a variable distance down the forearm into two branches. The dorsal or superficial branch emerges between the tendons of the ulnaris lateralis and flexor carpi ulnaris, and is continued as the lateral dorsal digital nerve on the lateral chief digit. The volar or deep branch descends along the superficial digital flexor, gives a branch to the suspensory ligament below the carpus, and unites with the lateral branch of the median nerve to form the lateral volar digital nerve. But there is much difference in the course and dissemination of the ulnar nerve in rabbit from other mammals. In rabbit, the ulnar nerve originated from the caudal trunk together with median and musculocutaneous nerves and then separated from them. It gave the caudal cutaneous antebrachii nerve at the caudal of antebrachium and rami muscularis at the level of the cubital joint. The nerve then divided into digital dorsal and palmar nerve V at the caudomedial of the antebrachium. Prior to spreading to the palmar and dorsal of the digital V, one branch originated from each of them which then spread to the skin and subcutaneous tissues of the sole.

(6) stated that there are similarities in the movement of median nerve and its

dissemination in different muscles and subcutis in dog, ox and horses; whereas in rabbit there is much difference in the courses of median nerve. (6) Stated that, the median nerve descends behind the brachial artery, passes over the medial epicondyle of the humerus, then under the pronator teres, and continues in the forearm under cover of the flexor carpi radialis. It gives branches below the elbow to the flexor and pronator muscles, and lowers down a volar branch to the skin on the medial and volar aspect of the carpus, and terminates between the superficial and deep flexor tendons by dividing into three volar metacarpal nerves. These descend in the first, second, and third intermetacarpal spaces and unite with the volar common digital nerves in forming volar proper digital nerves. (6) stated that, the median nerve is usually the largest branch of the brachial plexus. It descends over the insertion of the scalenus, crosses the medial face of the brachial artery, and reaches the anterior border of that vessel. It is easily recognized by its large size and the loop which it forms with the musculocutaneous nerve. (6) Stated that the median nerve in ox descends behind the brachial artery, passes over the medial epicondyle of the humerus, then under the pronator teres, and continues in the forearm undercover of the flexor carpi radialis. It gives branches below the elbow to the flexor and pronator muscles, and lowers down a volar branch to the skin on the medial and volar aspect of the carpus, and terminates between the superficial and deep flexor tendons by dividing into three volar metacarpal nerves. These descend in the first, second, and third intermetacarpal spaces and unite with the volar common digital nerves in forming volar proper digital nerves. In rabbit, the median nerve was the longest nerve of the plexus brachialis originating from the caudal trunk in common with the ulnar and musculocutaneous nerves as a common root. After leaving the caudal trunk, firstly the ulnar nerve and then near to the distal of the humerus, the musculocutaneous nerve separated. Median nerve did not give any branch until articulation cubiti level and then it gave two branches called; rami muscularis and interosseus antebrachial nerve on antebrachium. Then it ended as four branches; digital dorsal common I, II, III and IV nerves, at the central level of the palmar part of metacarpus. This brief information about the White New Zealand Rabbit with regards to the topographical location of the brachial plexus including the course and distribution of nerves originating from it, may give suggestions for clinicians and practitioners for their application in practical field.

CONCLUSION

Some suggested preventative measures are: aviary hygiene, cleanliness and preventive care.

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