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The anatomical structure of the brachial plexus of the guinea pig (*cavia porcellus*)

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ABSTRACT

Background: In this study, we described the anatomy of the brachial plexus of the guinea pig (*Cavia porcellus*). The description of the brachial plexus anatomy can contribute to the knowledge of the neuroanatomy of small mammals. Furthermore, it is a source of information for clinicians performing brachial plexus anesthesia in exotic animals such as the guinea pig (*Cavia porcellus*).

Materials and methods: *Cavia porcellus* cadavers were fixed in a 10% formalin solution. The examination of 20 specimens of this species allowed us to assess the extent of the brachial plexus, the nerves exiting it, and the extent of their innervation. Most commonly, it consisted of C6-T1 but could also include branches of C5 and T2. The plexus consisted of three trunks and four cords. We distinguished 15 nerves: n. subclavius, n. brachiocephalicus, n. dorsalis scapulae, n. suprascapularis, nn. subscapulares, n. axillaris, n. musculocutaneus, nn. pectorales craniales, n. radialis, n. medianus, n. ulnaris, n. thoracodorsalis, n. thoracicus lateralis, n. thoracicus longus, and nn. pectorales caudales. We elaborated the innervation range of all identified nerves and updated data from existing papers.

Results: We presented the detailed anatomy of the n. musculocutaneous, brachiocephalicus, and pectoral nerves, which were not distinguished in previous papers or for which the structure was insufficiently known, and compared our results with existing work.

Conclusions: Based on the innervation and the extent of the plexus, it can be confirmed that *Cavia porcellus* has a brachial plexus with a structure that is characteristic of rodents.

Keywords: rodent, nerves, roots**,** ventral branch

INTRODUCTION

The development of veterinary medicine requires in-depth knowledge of animal anatomy, particularly the anatomical variants of the basic elements of the body. The guinea pig (*Cavia porcellus*) is a rodent species of the Caviidae family. In the phylogenetic classification, the guinea pig is a representative of the Caviidae family. The Caviidae family is part of the large animal group Caviomorpha, which consists of, among others, the families Octodontidae, e.g. common degu (*Octodon degus*); Erethizontidae (New World porcupines); Caviidae, e.g. capybara (*Hydrochoerus hydrochaeris*), guinea pig, e.g. (*Cavia porcellus*); Chinchilloidea, e.g. long-tailed chinchilla (*Chinchilla lanigera*); Myocastoridae, e.g. (*Myocastor coypu*). Caviomorpha (South America, Caribbean, North America), together with Phiomorpha (species that occur in the Old World — Afro-Eurasia), co-form the Hystricognathi [39, 41].

Cavia porcellus is often used in scientific research on neurological and neuroanatomical issues [18]. Numerous publications confirm the ongoing interest in studying the anatomy of the nervous system in wild and domestic animals [32, 34, 50, 60]. One of the nervous system components of primary interest to researchers is the brachial plexus, a structure located in the cervicothoracic region and responsible for innervating the thoracic limb. The anatomy of the brachial plexus in rodents [4, 5, 10, 13, 16, 26, 35, 37, 51] and rabbits [49, 64] has been the focus of particular attention due to its translational outcomes. Based on numerous studies, the brachial plexus of mammals has been found to contain roots from the C4–T3 segments, depending on the species, and it branches into 12 or 13 peripheral nerves [5, 60]. However, an existing paper indicates a reduction in the number of nerves leaving the brachial plexus in guinea pigs (which do not include the dorsalis scapulae, subclavius, thoracodrosalis, or thoracicus lateralis nerves) [55]. In another study, these nerves were already highlighted, but n. musculocutanues and the second, caudal, pair of pectoral nerves were not distinguished [17]. There are other gaps in the existing work on the anatomy of the guinea pig's shoulder plexus, such as the absence of innervation of m. teres minor and m. scapulocalvicularis [17]. Moreover, the innervation ranges of some nerves that are questionable, such as the n. axillaris (according to the work, it only innervates the caput laterale of the m. triceps brachii, deltoideus, and cutaneus omobrachialis), need to be verified [17]. In addition, previous papers have not used digital methods to present their results.

According to researchers, the brachial plexus nerves are often selected for research on peripheral nerves because they are easier to access in terms of experimental damage than the nerves on the thoracic limb [56]. There are many similarities in the morphology of the innervation and vascularization of the thoracic limb in rodents to that in humans, which means that it can be used to study the treatment of brachial plexus injuries in humans [3, 65]. Updates on the guinea pig’s body structure continue to be presented; therefore, we decided that it was necessary to update the data on the brachial plexus as well.

The aim of this study was to describe the anatomical structure of the brachial plexus, the presence of individual nerves, and the innervation to the thoracic limb of the guinea pig and to compare this description with previous papers on guinea pigs.

MATERIALS AND METHODS

This study was conducted on 20 adult guinea pigs (9 female and 11 male), aged 11 months to 7 years. Cadavers were obtained from a veterinary clinic in Poland on a cooperative basis to carry out the study “Structure of the brachial plexus (*Plexus brachialis*) of domestic cavy (*Cavia porcellus*)” under the Grants4NCUStudents 5th edition of the “Excellence Initiative — Research University”. The animals’ average weight was 0.9 kg. The age data were obtained from the “XP clinic” program (an operational program for drug sales and patient registration used at the clinics from which the study material was obtained).

All cadavers of *Cavia porcellus* were opened through the abdominal muscles (into the abdominal cavity) and diaphragm (into the chest) and then immersed in containers (20 L in volume) filled with a fixative for two weeks. For the fixation of the cadavers, a 10% solution of buffered formalin was used (formalin 10%, Chempur, Piekary Śląskie, Poland; catalog number 114321735). After fixation, the corpses were rinsed for two days in a pool of water to ensure safe preparation. Safety was also ensured by using a ventilation system in the preparation room, which maintained 15 air changes per hour. The nerve structures were visualized with a 2% hydrogen peroxide solution (Chempur, catalog no. p.d.a. 118851937) (we lowered the concentration from 3% to 2% due to the size of the structures) [34].

All dissections were examined under a binocular stereomicroscope (Discovery L microscope, Delta Optical, Mińsk Mazowiecki, Poland). Dissection was performed using basic microanatomical instruments (e.g., Micro-Adson surgical tweezers and Castroviejo precision scissors). The preparations began with removing skin from the entire pectoral region and thoracic limbs. The first cut was made along the dorsum to begin the removal of skin and subcutaneous adipose tissue from the cervicothoracic region of the specimen. Skinning was performed gently, ensuring the preservation of the subcutaneous musculature from the spine to the pectoral region on both sides of the body. The removal of the skin from the brachium and distal part of the thoracic limb was also performed by gently separating the skin from the fascia and subcutaneous tissue. Then, the sternal attachments of the thoracic muscles were cut away so that the sagittal incision of the sternum could be performed without damaging them. After that, the organs filling the thoracic cavity were removed, along with the superfluous surrounding connective tissue and blood vessels. The individual bellies were cleaned and, if possible, separated from each other to reveal the course of individual nerves. When exposing the nerve was difficult, we decided in some cases to cut the belly to show the anatomy of the course of, for example, the n. brachiocephalicus and n. suprascapularis.

Photos were taken both during the dissection (to show the original runs) and of the finished dissected specimens to show the neuroanatomical details. The photos were taken with a Nikon D3200 camera (Tokyo, Japan). GIMP version 2.10.24 and Biorender (Toronto, Canada; https://www.biorender.com) were used to prepare the schemes and photos. The names of the anatomical structures were standardized according to the Nomina Anatomica Veterinaria [72].

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RESULTS

The brachial plexus arises in the cranial region and extends to the first rib, between the medial surface of the scapular region and the pectoral region. It runs through the axillary fossa to the shoulder (Fig. 1A–D). The brachial plexus of the guinea pig is composed of four or five nerve roots: C5–T1 (30%), C6–T1 (50%), or C6–T2 (20%) (Tab. 1). The roots form three trunks: the cranial (C5–C6), middle (C7), and caudal (C8–T2) (Tab. 2) (Fig. 2A, B). Each trunk has two divisions, meaning that there are six divisions in total. The fibers join to form four cords and fifteen nerves (Fig. 12). The roots of the cervical and thoracic nerves in the brachial plexus also form other nerve structures. Among others, the C5–C7 roots form the phrenic nerve. The C8 root communicates with the sympathetic nervous system, connecting the brachial plexus with sympathetic fibers.

The brachial plexus nerves are divided into short and long branches. The former is responsible for the innervation of the muscles of the scapula and the pectoral region, while the latter is mainly responsible for the innervation of the muscles of the brachium, antebrachium, and manus.

The short branches of the brachial plexus of the guinea pig consist of the supraclavicular and subclavicular parts. The supraclavicular part is located in the cervical fossa, whereas the subclavicular part is in the axillary fossa.

The largest was the n. axillaris, formed from the C6–C8 roots. A strong branch forming this nerve originated from C7, whereas the branch extending from C8, like the one extending from C6, was much less pronounced. The n. axillaris runs toward the shoulder joint (Fig. 6A, B). Before reaching the joint, the nerve branches into the muscular branch to the caudal part of the m. subscapularis, and another, stronger, branch branches into the m. teres major. Then, the n. axillaris runs between these muscles. The nerve then runs across to the caput longum of the m. triceps brachii, with a branch extending to the m. teres minor branch. The n. axillaris on the lateral side splits into two muscular branches for different parts of the shoulder muscle: the m. deltoideus (the pars acromialis and the pars scapularis). In addition, it branches into the m. cleidobrachialis (m. deltoideus pars clavicularis) (Fig. 1B). The last branch is the cutaneous branch, which is responsible for innervating the skin of the lateral surface of the brachium as n. cutaneus brachii lateralis cranialis. It passes between the deltoideus and brachialis muscles and runs distally on the lateral of the brachium. At the lateral surface of the elbow joint at the transition from the brachium to the antebrachium, it commingles with the cutaneous branches of the r. superficialis n. radialis.

The plexus nerve with the most cranial origin was the n. dorsalis scapulae, as it only ran from the C5 and C6 branch. N. dorsalis scapulae had a strong but short trunk, which quickly divided into two muscular branches. One of these branched off and immediately innervated the m. serratus ventralis cervicis. The other, which was much longer but thinner, ran between the fibers of the m. serratus ventralis cervicis toward the dorsum. In the space between the chest wall and the ribbed surface of the m. serratus ventralis cervicis, the n. dorsalis scapularis emerged and branched into several fine fibers innervating the m. rhomboidues capitis, m. rhomboideus cervicis, and m. rhomboideus thoracis.

The n. subclavius was formed from the C6 root and was responsible for innervating the m. subclavius and m. scapulocalvicularis (Fig. 7B). The m. subclavius was first innervated near the sternal attachment. After moving through this muscular branch, the subclavian nerve headed toward the shoulder joint, where it entered between the clavicular attachment of the m. subclavius and the clavicular attachment of the mm. pectorales profundus, reaching the m. scapuloclavicularis.

The n. suprascapularis was formed from C5–C6 (30%) or C6 (70%). It ran toward the shoulder joint. It then ran along the cranial border of the scapula and entered the supraspinous fossa. There, it branched between the fibers of m. supraspinatus. It then passed under the supraspinatus and curved around the spine of the scapula into the infraspinous fossa. There, in the fossa, it branched between the fibers of m. infraspinatus.

The n. brachiocephalicus was formed from the same branches as the suprascapular nerve (C5–C6 — 30% or C6 — 70%). It also headed toward the shoulder joint but entered between the clavicular attachment of the m. brachiocephalicus and m. scapuloclavicularis. Then, it ran between the m. cleidocephalicus and m. omotransversarius (Fig. 3 and Fig. 9 A and B). It then branched into the skin of the region cranially and medially from the shoulder joint and caudal part of m. platysma (cervical part) (Fig. 14).

Two (70%) (Fig. 1A) or three (30%) (Fig. 13A) nn. subscapulares nerves exist. One of them was formed from C6–C7; the other two were only formed from C6. They participated in the innervation of the m. subscapularis in the fossa subscapularis, but they joined it at different places: one was closer to the cranial border of the scapula, whereas the other was in the center of the subscapularis muscle.

The following nerves were responsible for the innervation of the pectoral region: the caudal pectoral nerves, cranial pectoral nerves, long thoracic nerve, lateral thoracic nerve, and thoracodorsal nerve.

The nn. pectorales caudales were a complex element of the brachial plexus of the guinea pig, because the deep pectoral muscles were well developed in this species. The nn. pectorales caudales stemmed from C8–T1 and ran alongside the n. medianus, n. ulnaris, and n. thoracicus lateralis. They detached from them at one-third of the brachium’s length and ran across the pectoral region. They then separated into three equal branches, one of which innervated the cranial part of the muscle. The second, and strongest, was responsible for the middle part of the muscle (but it can be seen that its fibers ran caudally), and the third branch ran along the sternum caudally (Fig. 4B).

The pectoral muscles of the guinea pig were also innervated by the nn. pectorales craniales, which stemmed from C7–C8, and they innervated the superficial pectoral muscles (m. pectoralis transversus and m. pectoralis descendens). The nn. pectorales craniales arose cranially in relation to the others. It branched into several small fibers just at the sternal muscular attachment. Two main branches of the first order arose, the more expressed of which was directed toward the brachial attachment and along the sternal attachment caudally (Fig. 4A). The second branch of the first order was responsible for the middle and cranial parts of the superficial pectoral muscle. It was divided into two branches that innervated the middle part of the muscle. One of these, the cranial branch, gave rise to a smaller branch that is responsible for the cranial part of the muscle near the sternal attachment.

The n. thoracicus lateralis consisted of C8–T1. The fibers of the n. thoracicus lateralis were connected to the nn. pectorales caudales; they co-formed the trunk at the initial stage (Fig. 5B). Then, after the nn. pectorales caudales disconnected, the n. thoracicus lateralis moved in its own direction (along the caudal margo of the m. latissimus dorsi). As two separate branches, the lateral thoracic nerve moves dorso-caudally to branch between the fibers of the m. cutaneus trunci (Fig. 5A).

The n. thoracicus longus consisted of C6 and C7. The n. thoracicus longus ran in the same direction as the lateral thoracic nerve—to the third rib or third intercostal space. There, the fibers of the n. thoracicus longus ran caudally and upward toward the m. serratus ventralis thoracis, which they innervated.

The n. thoracodorsalis was formed from C7 and C8. This nerve consisted of fibers of the n. radialis and n. axillaris. In turn, it was responsible for innervating the m. latissimus dorsi. After disengaging from these two nerves, it ran to the caudal border of scapula, where, at its height, it branched into two branches destined for the latissimus dorsi muscle (Fig. 7A).

The long branches of the guinea pig's brachial plexus:

The n. radialis was formed by combining C6 with T1. The n. radialis was mainly formed from C8. The n. radialis communicated with the n. axillaris before it branched into the muscular branch. The first was a thin branch that ran to the m. tensor fasciae antebrachii. The next branch, which was much thicker, ran to the caput longum of the m. triceps brachii. Another branch ran to the caput mediale of the m. triceps brachii. On the medial side of the shoulder, there was also a branch to the caput laterale of the m. triceps brachii, which ran along with the main part of the nerve to the lateral side of the thoracic limb and then branched off in the direction of the m. anconeus. The radial nerve first entered between the caput longum and the caput mediale of the m. triceps brachii. It then moved around the humerus, and on the lateral side of the brachium, it was located between the caput laterale of the m. triceps brachii and the m. brachialis (Fig. 8A, B). Still, at the shoulder level, the radial nerve branched into the n. cutaneus brachii lateralis caudalis and then split into the ramus profundus and the ramus superficialis (Fig 1C). Before passing through the level of the elbow joint, a muscle branch was first formed in the direction of flexion of the limb for the m. brachioradialis. Then, the m. extensor carpi radialis longus and brevis were innervated. At the level of the antebrachium, a branch for the m. supinator arose first. Then, a strong branch was formed for the m. extensor digitorum communis, m. extensor digitorum lateralis, m. extensor carpi ulnaris, m. abductor pollicis longus, and m. extensor digiti I. The latter (ramus superficialis) ran to the cranial surface of the antebrachium. The ramus superficialis ran from the antebrachium to the dorsal part of the wrist and then to the metacarpus. The n. radialis shared the whole path from the elbow joint with the v. cephalica. Then, at the metacarpus level, it split into the nn. digitales dorsales communes II, III, and IV — and the n. digitalis dorsalis I abaxialis.

The n. ulnaris was formed from C8–T1 (C8–T2). Initially, it ran along with the median nerve and then moved toward the medial epicondyle of the humerus. At the level of the middle of the humerus, the ulnar nerve gave rise to the n. cutaneus antebrachii caudalis, which was its first branch, reaching the caudal surface of the antebrachium. It then sent off a muscular branch to the m. epitrochleoanconeus. The n. ulnaris then ran under the m. epitrochleoanconeus. The ulnar nerve, close to the elbow, ran between the m. flexor carpi ulnaris and the m. flexor digitorum superficialis. At the middle level of the forearm, it sent a muscle branch to the m. flexor digitorum profundus. After all the muscle branches, it had a dorsal branch, which passed to the palmar side of the limb (palmar branch) at the level of the wrist, where it branched into a superficial branch that is responsible for innervating the lateral side of the V finger and a deep branch intended for the metacarpus.

The n. medianus stemmed from C7–T1 and ran toward the elbow joint with the a. brachialis and the n. ulnaris. In the axillary fossa, the n. musculocutaneus and the n. medianus have a common part, where the two nerves exchanged fibers with each other. Depending on the individual, the n. musculocutaneus retains more or less communication with the n. medianus at the level of the brachium (Fig. 13A, B). When it passed to the antebrachium, it separated from the ulnar nerve and ran between m. pronator teres and m. brachialis and penetrated to deeper part of the musculature. There, n. medianus sent off muscular branches to the pronator teres, flexor carpi radialis, palmaris longus, flexor digitorum profundus, pronator quadratus, and flexor digitorum superficialis (Fig. 11). After all the muscular branches, the n. medianus ran under m. palmaris longus and came out on the ventral surface of the antebrachium midway along its length. The n. medianus was close to the n. ulnaris, again in the wrist region. Together, they passed through the mass of connective tissue of the base of the metacarpal pad to the palmar side of the hand. The end sections of the n. medianus were responsible for the innervation of all digits, except the lateral side of the V finger on the palmar side.

The n. musculocutaneus stems from C5–C8. It develops from two strong branches, C7 and C8, and two smaller ones, C5 and C6. The fibers from these roots form a common short trunk of the n. musculocutaneus, which briefly interacts with the trunk of the n. medianus. The n. musculocutaneus innervates the m. coracobrachialis, m. biceps brachii, and m. brachialis. After the muscular branches end, the n. cutaneus antebrachii medialis is formed. It passes under the m. biceps brachii on the side of the elbow joint and then emerges on the surface of the antebrachium between the m. biceps brachii and the m. brachialis. In addition to its strong connection to the n. medianus, the n. musculocutaneus at the level of the antebrachium, it connects to the n. radialis at the level of the mid-antebrachium and co-forms the common dorsal digital nerve II. Its terminal branches end in the skin as the n. cutaneus antebrachii medialis (Fig. 2D).

DISCUSSION

In this study, we report that the guinea pig's brachial plexus can vary from one individual to another. In addition, in contrast to previous data, in the present study, we detected participation of the C5 branch (30% of cases) in the formation of the brachial plexus in guinea pigs [55]. In 1975, Cooper et al., similarly to our study, revealed the participation of the C5 branch in the formation of the brachial plexus, but they did not report the participation of the T2 branch in the formation of any of the nerves [17]. In contrast, in Spix's yellow-toothed cavy (*Galea spixii*), which is closely related to the guinea pig, the brachial plexus presents a series of ventral branches of the C6–T2 or, in some cases, the C6-T3 spinal nerves [5]. Another representative of caviomorpha is rock cavies (*Cerodon rupestris*), which show a similar distribution of abdominal branches to the ones discovered by us. The proportion of C5 was present in 35% of cases, and in 55%, there was a connection with T2 [57]. Caviidae belong to the large infraorder Hystricognathi; therefore, we expect similarities with other representatives of this infraorder. One such representative is the dwarf porcupine (*Sphiggurus villosus*) [25]. In this case, the C5 branch enters the brachial plexus in 73.3% of individuals [25]. In contrast, the T2 branch is present in all individuals. Others from this group are the nutria (*Myocastor coypus*) (C5 to T1) [66] and the capybara (*Hydrochaeris hydrochaeris*) (C4-T1) [26]. The guinea pig's brachial plexus may also be similar to representatives of the Myomorpha suborder [9] (Table 3). Although we did not demonstrate this in this study, we cannot rule out the possibility of a prefixed type of brachial plexus that may exist in Mongolian gerbil (*Meriones unguiculatus*) [4, 31, 68] or djungarian hamster (*Phodopus sungorus*), which is characterized by a range of C4–T2 branches [35]. We noted similarities in the brachial plexus of rodents and primates. Hominidae have a brachial plexus that normally consists of C5-T1 branches, but a combination of C4–T2 is also possible in rare cases [14]. Non-human primates, in the case of *Callithrix jacchus* and *Macacca mulatta*, have a *plexus* composed of C5–T1, with possible participation of C4 [23, 58]. Of the carnivores, the species of Procyonidae most closely resemble the brachial plexus of rodents in their range. Both in *Potos flavus* [24], *Procyon cancrivorus,* and *Nasusa nasua [69],* the brachial plexuses are characterized by a C5–T2 range. Canidae and Felide, on the other hand, mostly have a plexus composed of C6–T1 [12, 33, 34]. All of the above-mentioned mammals have a cervical spine consisting of seven cervical vertebrae. An interesting exception is the order Pilosa, whose representatives, such as *Bradypus variegatus*, have 8–9 cervical vertebrae [1, 45]. Consequently, the number of spinal nerves leaving the spinal cord at this location also differs. The *brachial* plexus of *Bradypus variegatus* consists of C5, C6, C7, C8, C9, T1, and T2 [1] or C8, C9, C10, T1, and T2 [45].

The brachial plexus of the guinea pig is composed of three trunks. In the literature, we found information on the formation of one trunk in the mole-rat (*Spalax leucodon*) and two in the squirrel (*Sciurus vulgaris*) [8, 9], as well as two trunks in *Myrmecophaga tridactyla*, a representative of the Marsupials [62]. On the other hand, three trunks, as found in the pig, are also present in rats and humans [67, 68]. A similar trunk arrangement to that in our work has also been detected in dwarf porcupine and *Bradypus variegatus* [1, 25, 45].

Species may differ in the number of nerves exiting the brachial plexus [44]. In addition, peripheral nerves in different species originate from different roots (Tab. 1). Potter et al. [55] found nine nerves in the guinea pig but failed to show the long pectoral, lateral pectoral, and thoracodorsal nerves. Guimares et al. [36] also did not indicate the presence of the long pectoral and lateral pectoral nerves in nutria (*Myocastor coypus*). Cooper et al. [17], on the other hand, in their description of the plexus anatomy in the guinea pig, did not identify the n. musculocutaneus or n. brachiocephalicus, and they cited only one pectoral nerve (*n. pectoralis*) that is responsible for innervating both the superficial and deep pectoral muscles. However, nerves such as the n. scapularis cranialis were identified [17].

Despite the NAV guidelines, the n. dorsalis scapulae is often not classified as a component of the brachial plexus. In the works in which n. dorsalis scapulae was mentioned, it had a similar range of innervation as in our guinea pigs. The n. dorsalis scapulae has also been mentioned in nutria [66] and, as identified by Cooper, innervates the m. rhomboideus [17]. On the other hand, in the rat, it is responsible for rhomboid major and minor, m. occipitoscapularis, and m. levator scapulae [31]. The nerve scapularis dorsalis was also identified in capybara and is responsible for m. serratus ventralis cervicis and m. rhomboideus cervicis and thoracis [26]. In Wistar rats, beyond stating its presence, the extent of its innervation has not been discussed [3]. However, it is known that the area of its innervation is also impacted by the dorsal branches of the cervical spinal nerves.

Araujo Jr et al. [5] described all the brachial plexus nerves in Spix's yellow-toothed cavy, except for the subclavian nerve. In our study, we established the presence of this nerve, which is responsible for innervating the subclavian and scapulocalvicularis muscles. The subclavian muscle is present in many species of rodents [17, 28] and primates [23, 63] but is absent in canids [34]. The subclavian nerve is responsible for innervating only the subclavian muscle in chinchillas [16, 28], Wistar rats [3], laboratory rat (*Rattus norvegicus*) [31], and *Macaca mulatta* [58]. In Cooper's work [17] on the guinea pig, the subclavian nerve was found to be responsible for both the subclavian muscle and, together with the n. pectoralis, the pectorales muscles. In Potter et al.'s [55] work on the guinea pig, the n. subclavius is not mentioned. In Günther's vole (*Microtus guentheri*), the n. subclavius is responsible for m. brachiocephalicus and m. cutaneous omobrachialis [42]. We found key similarities to our work in nutria [66] and Hystricomorpha, as described by Parsons in 1894 [53]. In their case, the n. subclavius is responsible for innervating the m. subclavius and m. scapuloclavicularis. The scapulocalvicularis muscle is a specific muscular structure for Hystricomorpha, including the guinea pig. It is a muscle that extends from the intersectio clavicularis to the scapular cranial border and scapular spine [53]. It covers the m. supraspinatus with its surface and lies in a transverse position to the m. omotransversarius. Its clavicular attachment is common to the brachiocephalic muscular arrangements [30]. In addition, the intersectio clavicularis is the site of attachment for the subclavian m. and deep pectoral muscles [22, 30]. Depending on the taxonomic group, the subclavian and scapulocalvicularis muscles may constitute a single sterno-scapularis muscle, as in the Hystricidae [53]. The exception is the Sphingurus group, in which the muscle is divided into subclavian and scapulocalvicularis parts [53]. Estruc et al. [25] described the brachial plexus nerves of one of the representatives of this group, the *Sphingurus villosus*. However, the subclavian and scapulocalvicularis muscles were not included in the description, because they were cut off before the analysis; therefore, the subclavian nerve itself was also not mentioned by the authors [25]. Consistent with our study, Parsons [53] also indicated that in the family Caviidae (*Ceredon rupestris*), the subclavius and scapuloclavicularis muscles are separate muscles with a shared attachment on the small clavicle. Both muscles in these species are innervated by the subclavius nerve [53]. Their common origin and the fact that, in some species, these muscles are one and the same may be the reasons for their joint innervation [30].

One of the muscles belonging to the brachiocephalic muscle system is the cleidobrachialis [30]. Despite its close relationship with the muscles discussed above, it has a different innervation. From a developmental point of view, the cleidobrachialis muscle is part of the deltoideus muscle and is listed as the pars of the musculus deltoidues [22]. Therefore, like the other two parts (the scapularis and acromialis), the cleidobrachialis is innervated by the axillary nerve [22]. Earlier nomenclature referred to the axillary nerve as the circumflex nerve. Such nomenclature is used in older texts when innervation of the clavicular part of the shoulder muscle by the n. circumflex was indicated in the *Agouti paca*, *Sphingurus villosus*, *Hystrix cristata*, and *Chinchilla laniger* species [53]. Other authors have indicated a thoracic origin of the cleidobrachialis muscle in crested agouti (*Dasyprocta cristata*), which is, according to Mivart and Murie [48], thought to be related to its innervation via the n. pectoralis. According to our study, the m. cleidobrachialis is innervated by the axillary nerve. The detailed anatomy of the brachiocephalic muscular arrangements is shown in the diagram in Fig. 3. In addition to the m. deltoideus, the axillary nerve is usually responsible for innervating the m. subscapularis at the caudal edge of the scapula, the m. teres major, and the m. teres minor. In the work by Cooper et al. [17], the axillary nerve in the guinea pig does not innervate the m. teres major (according to the authors, only the subscapular nerve is responsible for this) or the m. teres minor (no nerve is given for this muscle), while Potter and Brueck [55] do not specify the extent of innervation of the axillary nerve. The cutaneous extension of the axillary nerve, the n. cutaneus brachii lateralis cranialis, is responsible for innervating the lateral surface of the brachium [4, 5]. However, in the case of *Sphinggurus villosus*, the authors point to innervation of the m. infraspinatus by the n. axillaris [25]. In nutria and capybara, on the other hand, the n. axillaris is responsible for innervating part of the m. triceps brachii [26, 66]. The axillary nerve and the caput longum of the m. triceps brachii remain in close contact. The former name of the axillary nerve (circumflex nerve) refers to its course, which involves the surgical neck of the humerus. One of the characteristic topographic sites for the axillary nerve is the quadrangular space or the space demarcated by the m. teres minor, the m. teres major, the caput longum of the m. triceps brachii, the surgical neck of the humerus, or the subscapularis muscle [52]. As our analysis shows, the axillary nerve of the guinea pig also runs through the quadrangular space. Other authors describing only the course of the axillary nerve have indicated that it enters between the m. subscapularis and the m. teres major [4, 5]. However, as indicated by comparative studies of rodent musculatures and those of other species, the axillary nerve should run through the quadrangular space.

The n. brachiocephalicus is mainly mentioned in papers devoted to the Carnivora order in Procyonidae [34, 69], Canidae [34, 70], and Felidae [20, 33, 61]. However, it is not mentioned as part of the primates' plexus [23, 58]. In Carnivora, the most common way this nerve diverges from the cranial part of the brachial plexus is as a branch of the suprascapular nerve or separate nerve, which has been reported more than once [40, 69, 70]. Depending on the species, its fibers are responsible for innervating the brachiocephalic muscular arrangements [20, 61]. The course and extent of innervation of the n. brachiocephalicus, which is mentioned in our study, are most similar to the description of the n. brachiocephalicus in *P. cancrivorus* and *N. nasua* [69]. Its course was characterized by its location between the m. cleidocephalicus and m. omotransversarius [69], and it was determined to be responsible for the "cranial surface of the shoulder and proximal half of the cranial surface of the brachium" [69]. Unlike in Carnivora, it is not responsible for the innervation of the m. brachiocephalicus, infraspinatus, or cleidobrachialis [69]. In our study, we show that it is responsible for the innervation of the cranial skin surface of the shoulder and the caudal part of the m. platysma (cervical part). Therefore, in the guinea pig, it more closely resembles n. supraclavicularis [31]. The previously described innervation of the m. platysma originated from the cervical plexus via the n. transversus colli caudalis [17]. We found another similarity with Cooper's [17] description, where the n. scapularis cranialis is described to have a similar course to the n. brachiocephalicus that we identified. However, the extent of innervation of this nerve was not mentioned. In mammals, the m. platysma has a double innervation; in the facial part, the fibers of the n. facialis are responsible, and in the caudal part, the cervical spinal nerves are responsible [38], in this case via C5–C6 and the n. brachiocephalicus.

Similarly to that of the guinea pig, the radial nerve of Spix's yellow-toothed cavy receives its main branch from C8, which is different from the origin of the radial nerve in the nutria, where it is mainly formed from the C7 roots [36]. The most significant difference in the distal end of the limb is the lack of the common dorsal nerve of digit I, because the guinea pig does not have digit I. This nerve and digit I are also absent from Spix's yellow-toothed cavy [5]. Due to the absence of this digit, the structure of the n. radialis is also different. In rodents, this nerve usually originates from the C8–T1 roots [36, 59] or C7–T1 [4, 16, 28], but it can also stem from a larger number of roots, e.g., in the porcupine, where it stems from C6–T1 [10]. After the innervation of the antebrachium muscles, there is no muscle branch for the digit I flexor in the guinea pig. This muscle branch is also absent from Spix's yellow-toothed cavy [5]. According to our work, the radial nerve, on the medial side, runs between the long head and the medial head of the m. triceps brachii. In another work on the guinea pig, the n. radialis ran between the humerus and the m. triceps brachii [55]. The extent of innervation of the radial nerve is generally constitutional among mammals. However, significant differences arise in the supply of the m. anconeus (epitrochleoanconeus lateralis [22, 29]). From a physiological and functional point of view, the m. anconeus is part of the triceps brachii muscle (it has attachments from the humerus (lateral epicondyle) to the olecranon of the ulna and is blended with the m. triceps brachii [22]) and is, therefore, innervated by the radial nerve in different species: capybara [26], chinchilla [28], paca [59], and nutria [66]. Other authors have found that m. anconeus is innervated by the ulnar nerve in G. spixii [5] and C. gambianus [43], which probably describes the innervation of m. epitrochleoanconeus — otherwise known as m. epitrochleoanconeus medialis — which lies on the medial side and covers the ulnar nerve (from the medial epicondyle to the olecranon of the ulna). In our work, we distinguished a distinct m. epitrochleoanconeus and m. anconeus that were fused to the m. triceps brachii. The same innervation was indicated, e.g., in nutria [66] and rat [31] (the n. radialis innervates the m. anconeus, and the n. ulnaris innervates the m. epitrochleoanconeus). In addition, in a close relative of the guinea pig, the Kerodon moco (*Ceredon rupestris*), the m. anconeus is also innervated by the n. radialis, and m. epitrochleoanconeus supplies the n. ulnaris [53].

The median nerve may be formed by two branches, e.g., by C8–T1 in the nutria [36], by C8–T1 in paca [59], and by T1–T2 in chinchilla [16], or it may be formed by four branches, e.g., by C6–T1 in capybara [26]. The median nerve comes into contact with various nerves; for example, the communication between the musculocutaneous and median nerves near the elbow and that near the medianus–ulnaris trunk is characteristic of Canidae [19, 47]. The musculocutaneous nerve originates from roots C5–C8 in species such as rats [15]. However, it is different from what Araujo Jr [5] presented in his study on Spix's yellow-toothed cavy, i.e., C6–C7 or C7–C8. A study on the brachial plexus of the capybara, a close relative of the guinea pig, indicated that the musculocutaneous nerve is closely related to the n. medianus [6, 26]. Fioretto et al. [26] even classified the musculocutaneous and median nerve as one — the n. medianus–musculocutaneus. A similar anatomy was demonstrated in our study, where the musculocutaneous nerve retained connectivity with the median nerve, and a branch even departed towards the coracobrachialis muscle from the level of this connection. In other individuals, where the connection was longer, a muscular branch for the biceps brachii muscle also departed from the shared trunk. However, the continuation of the musculocutaneous nerve at the level of the brachium remained distinct, and a typical medial antebrachial cutaneous nerve was formed. Moreover, the branching of the median nerve at the level of the brachium also remained unchanged and was consistent with the general characteristics of the course of the median nerve in rodents. According to the description of Cooper (1975), the n. musculocutaneus is not present at all, but in our study, its part before the connection with the median nerve was distinct, and the divisions that make up the separate musculocutaneous nerve were clearly visible (Fig. 10A, B) [17]. Similar to our description, Aydin et al. [7] also indicated that the n. medianus and n. musculocutaneus share a single trunk at an early stage in *Hystrix cristata*. In other rodents, a close musculocutaneous and medial relationship, such as that in the guinea pig and capybara, is not present [5, 16, 28].

The median nerve innervates the antebrachium flexors together with the ulnar nerve. In rodents, the ulnar is responsible for innervating the caudal skin surface of the antebrachium, the m. epitrochleoanconeus, the m. flexor carpi ulnaris, the m. flexor digit V, and the digital cutaneous region of the hand. In addition, in nutria, the n. ulnaris is responsible for the m. palmaris longus in *M. coypus* [66] and the m. interosseus in chinchilla [28]. Interestingly, the ulnar nerve in guinea pig is only formed from T1 according to the work by Potter and Brueck [55]. Guinea pigs often suffer from paralysis of the median and ulnar nerves. The paralysis of these nerves is physiologically manifested by the slower conduction of nerve impulses in the antebrachium and hand [27]. According to Fullerton and Gilliatt [2, 27], this paralysis is caused by the compression of the transverse cartilage in the metacarpal pad. The median and ulnar nerves, passing under this cartilage and encountering the fibrous tissue, become thinner. Our study also showed the proximity of these structures of the nervous and locomotor systems. Fullerton et al. [27] even observed demyelination in the histological examination conducted as part of their study.

The caudal pectoral nerves are formed similarly to in other species, e.g., the long-tailed chinchilla, C8–T1 [28], and Agouti paca, C8–T1 [59]. The cranial pectoral nerves stem from C6 [36] or C7 in nutria [66], but they are absent in capybara [26]. On the other hand, according to Cooper et al. [17], in guinea pigs, the cutaneus omobrachalis, which are deep and superficial pectoral muscles, are supplied by the n. pectoralis. In contrast, our work distinguishes between the pectoral nerves for the mm. pectorales superficiales (m. pectoralis transversus and m. pectoralis descendens) and the mm. pectorales profundus. On the other hand, in Spix's yellow-toothed cavy, the n. pectorales caudales in the figures appear much less pronounced compared with those in our study. Moreover, they arise close to the nn. pectorales craniales, mainly from C7–C8 [5]. In guinea pigs, the n. petorales caudales and n. thoracicus laterlais form a single trunk. Similar descriptions are lacking in the literature, but in one recent paper on *Sphingurus villosus*, a diagram of the brachial plexus shows the close relationship of these two nerves [25]. The innervation range of the n. thoracicus lateralis is well understood and, among individual species, is mainly responsible for the innervation of the m. cutaneus trunci [5, 16, 28, 66].

Researchers agree that the thoracodorsal nerve only innervates the latissimus dorsi muscle [10, 16]. In addition, the long thoracodorsal nerve also plays the same role in each species, that is, innervating the m. serratus ventralis thoracis [5, 31, 66]. Another nerve with a similar course and range of innervation is the n. suprascapularis. In most species, it is responsible for innervating the m. supraspinatus and m. infraspinatus (Tab. 5). One exception is Chinchilla laniger, where n. suprascapularis is responsible for the innervation of m. deltoideus (pars acromialis) [28].

The nn. subscapulares may be present in a variable quantity in different species. Most commonly, it is represented by two thin fibers that diverge equidistantly, as in chinchillas [16]. This is also how the subscapular nerves were formed in our study. In studies by Cooper et al. [17] and Potter et al. [55] on the brachial plexus in guinea pigs, the subscapular nerves were represented by one or three branches. In Potter's paper [55], we suspect that this may have been due to confusion, as they claimed that the extent of innervation for one of the three subscapular nerves was responsible for the m. thoracodorsalis. In Cooper's work [17], on the other hand, the subscapular nerves were also determined to be responsible for innervating the m. teres major. A similar situation was shown by Taketani [66], who showed that in nutria, the subscapular nerves are also responsible for the m. teres major and represented by three fibers. In the work by Aydind [7], in *Hystrix cristata*, the m. teres major also exhibits innervation from the nn. subscapulares, but the two subscapular nerves are distinguished.

A limitation of this study may be the scarce availability of photographs of the musculature and neuroanatomy of the guinea pig in the literature. There are several articles and books on the anatomy of these species, but the use of digital imaging tools is rare.

CONCLUSIONS

The aim of the present study was to describe the anatomical structure of the guinea pig's brachial plexus and compare it with existing descriptions for this species. Furthermore, we conducted a comparison with other phylogenetic groups and discuss the results. According to the results obtained, we conclude that the guinea pig shows a structure that is characteristic of its taxonomic group, having a brachial plexus composed of C5–T2. We also confirmed that the composition of the roots can change slightly, unlike the number of nerves in the brachial plexus, which was invariant in all individuals (except nn. subscapulares). There are key differences between our results and those of previous reports, particularly the presence of n. musculocutanues. We also demonstrated the presence of a branch that is responsible for the cutaneous innervation of the shoulder joint region, as well as the innervation of the m. platysma (cervical part). We named this branch n. brachiocephalicus due to the characteristic course between m. cleidocephalicus and m. omotransversarius. Furthermore, we provided a detailed description of the anatomy of both thoracic nerves, of which the caudal pectoral nerve has not been mentioned in recent work on guinea pigs. Our paper completed the gaps in muscle innervation, identifying n. subclavius as responsible for m. scapulocalvicularis. The revision of other brachial plexus nerves, including the n. axillaris, provided a complete picture of the anatomical structure of the brachial plexus. Furthermore, this work provides the literature with comprehensive photographic documentation of the normal anatomy of the guinea pig’s brachial plexus, which has been absent to date.

ARTICLE INFORMATION AND DECLARATIONS

Ethics statement

The authors confirm that they followed the journal's ethics policy. Only animal cadavers were used, so ethical approval was not required. And the use of research material is in accordance with the national law of January 15, 2015. (Law of January 15, 2015, on the protection of animals used for scientific or educational purposes (Journal of Laws, item 1682).

Author contributions

Conceptualization: A.G. and M.Z. Methodology: A.G. and M.Z. Formal analysis: A.G. and M.Z. Investigation: A.G. Writing — original draft preparation: A.G. Writing — review and editing: A.G. and M.Z. Visualization: A.G. Supervision: M.Z. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

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Table 1. Formation of the nerves of the brachial plexus of the guinea pig (*Cavia porcellus*), including the extent of innervation of individual nerves.

Nerve	Origin	Left [%]	Right [%]	Innervation
Brachiocephalicus	C6 (C5–C6)	65 35	75 25	skin of the shoulder and neck; platysma (cervical part)
Dorsalis scapulae	C5–C6 C6	30 70	30 70	m. rhomboideus capitis, m. rhomboideus cervicis, m. rhomboideus thoracis, and m. serratus ventralis cervicis

Subclavius	C6	100	100	m. subclavius and m. scapuloclavicularis
Suprascapularis	C6–C7 (C5–C7)	65 35	75 25	m. supraspinatus and m. infraspinatus
Subscapulares	C6–C7 C6	60 40	75 25	m. subscapularis
Axillaris	C6–C8	100	100	m. subscapularis, m. teres major, m. teres minor, m. deltoideus (pars scapularis and acromialis), and m. cleidobrachialis
Musculocutaneus	C6–C8 (C5–C8)	65 35	75 25	m. coracobrachialis, m. biceps brachii, and m. brachialis; skin of the antebrachium (medial face)
Pectorales craniales	C7–C8	100	100	Mm. pectorales superficiales
Radialis	C6–T1	100	100	m. tensor fasciae antebrachii, m. triceps brachii, m. brachioradialis, extensor carpi radialis longus, m. extensor carpi radialis brevis, m. extensor digitorum communis, m. extensor digitorum lateralis, m. extensor carpi ulnaris, supinator, anconeus, abductor pollicis longus, and m. extensor digiti I
Medianus	C7–T1	100	100	m. pronator teres, m. flexor carpi radialis, m. flexor digitorum profundus, m. pronator quadratus, m. flexor digitorum superficialis, and palmaris longus
Ulnaris	C8–T1 (C8–T2)	75 25	85 15	m. flexor carpi ulnaris, m. flexor digitorum profundus, and m. epitrochleoanconeus,
Thoracodorsalis	C7–C8	100	100	m. latissimus dorsi
Thoracicus lateralis	C8–T1	100	100	m. cutaneus trunci muscle
Thoracicus longus	C6–C7	100	100	m. serratus ventralis thoracis
Pectorales caudales	C8–T1	100	100	mm. pectorales profundus

Table 2. Tthe variation in the structure of the brachial plexus and nerve trunks according to the side of the body of the guinea pig.

	Roots	Total number	Left side [%]	Right side [%]
Brachial plexus	C6–T1	20 (50)	8 (20)	12 (30)
	C5–T1	12 (30)	7 (17.5)	5 (12.5)
	C6–T2	8 (20)	5 (12.5)	3 (7.5)
Cranial trunk	C6	28 (70)	13 (32.5)	15 (37.5)
	C5–C6	12 (30)	7 (17.5)	5 (12.5)
Middle trunk	C7	40 (100)	20 (50)	20 (50)
Caudal trunk	C8–T1	32 (80)	15 (37.5)	17 (42.5)
	C8–T2	8 (20)	5 (12.5)	3 (7.5)

Table 3. Comparison of brachial plexus ranges in different rodent species.

Nerves	**Animal** *Microtus guentheri* **[42]**	*Galea spixii* **[5]**	*Myocastor coypus* **[66]**	*Cavia porcellus* **[17]**	*Phodopus sungorus* **[35]**	*Agouti Paca* **[59]**	*Chinchilla lanigera* **[28]**
Brachial plexus range	**C5–T1**	**C6–T3**	**C5–T1**	**C5–T1**	**C4–T1**	**C5–T2**	**C6–T1**
Radialis	C7–T1	C7–C8, C7–T1, C7–T2, C8–T1, C8–T2, C8–T3	C6–C7	C7–T1	C7–T1	C7–T1	C7–T1
Axillaris	C6–C7	C6–C7	C6–C7	C6–C7	C5–C7	C6–C7	C6–C7
Medianus	C7–T1	C7–T1, C7–T2, C8–T1, C8–T2, C8–T3	C7–T1	C7–T1	C6–T1	C8–T1	C7–T1
Ulnaris	C7–T1	C7–T2, C8–T1, C8–T2, C8–T3	C8–T1	C7–T1	C8–T1	C8–T1	C7–T1
Musculocutaneus	C7–C8	C6–C7, C6, C7–C8	C6–C7	C7–C8	C5–C7	C6–C8	C6–C7
Suprascapularis	C5–C6	C6, C6–C7	C5–C6	C6–C7	C5(C4–C5)	C5–C7	C6
Subscapulares	C6–C7	C6–C7	C5–C7	C6–C7	C5–C6	C6	C6–C7
Pectorales craniales	C6	C6–C7	C7	C7–C8	C6–C7	C5–C8	C7

Pectorales caudales	C8–T1	C7–C8, C7–T2, C7–T3, C8, C8–T1	C8–T1	–	C7–T1	C8–T1	C8–T1
Thoracicus longus	C8–T1	C6–C8, C7–C8, C7–T1, C7–T2, C8–T2	C6–T1	C7–C8	C7–C8	C7–C8	C7–C8
Thoracicus lateralis	C8–T1	C8–T1, C8–T2, C8–T3	C7	C7–T1	C8–T1	C8–T2	C8–T1
Thoracodorsalis	C7–C8	C8–T1, C8–T2, C8–T3	C7	C7–T1	C6–T1	C8–T2	C8
Brachiocephalicus	–	–	–	–	–	–	–
Dorsalis scapulae	–	–	C5	C5–C6	–	–	
Subclavius	C5–C6	–	C6–C7	–	–	–	–

	Animal					
Nerves	***Cavia porcellus* [55]**	***Cricetomys gambianus* [43]**	***Meriones unguiculatus* [4]**	***Hydrochaeris hydrochaeris* [26]**	***Chinchilla lanigera* [16]**	***Sphingurus villosus* [25]**
Brachial plexus range	**C6–T1**	**C5–T1**	**C5–T1**	**C4–T1**	**C5–T2**	**C5–T2**
Radialis	C7–T1	C7–T1	C7–T1	C6–T1	C8–T2	C5–T2, C6–T2, C7–C8, C7–T2, C8–T1, C8–T2
Axillaris	C6–C7	C6–C7	C5–C7	C5–C8	C6–C7	C5–C6, C5–C7, C6, C6–C7 C6–C8, C7, C7–C8, C7–T2
Medianus	C7–T1	C6–T1	C7–T1	C6–T1	C7–T1	C5–T2, C7–T2, C8–T2, T1–T2

Ulnaris	T1	C7–T1	C7–T1	C6–T1	T1–T2	C7–T2, C8–T2, T1–T2
Musculocutaneus	C6–C7	C7–C8	C5–C7	C6–T1	C7	C5–C6, C5–C7, C6–C7, C6–C8, C7, C7–C8
Suprascapularis	C6	C5–C6	C4–C6	C4–C7	C5–C6	C5, C5–C6, C5–C7, C6, C6–C7
Subscapulares	C6–C8	C6–C7	C5–C6	C5–C7	C6–C7	C5–C6, C5–C7, C6, C6, C7, C6–C8
Pectorales craniales	C7	C5–C6	C5–C6	–	C7–T2	C5–C6, C5–C7, C6–C7, C6–C8, C7–T2
Pectorales caudales	C8–T1	–	C7–T1	–	T1–T2	C7–C8, C8, C8–T2, T1–T2
Thoracicus longus	C7	C7–T1	C7–T1	C6–C8	C6–C7 C7 C6–C8	C7, C8, C8–T2, T1–T2
Thoracicus lateralis	–	C8–T1	C7–T1	C7–T1	T1–T2	C8–T2, T1–T2
Thoracodorsalis	–	C6–T1	C7–T1	C6–T1	C8	C5–T2, C6–C7, C7–C8, C7–T1, C7–T2, C8–T1
Brachiocephalicus	–	–	–	–	–	–
Dorsalis scapulae	–	–	–	C4–C5	–	–
Subclavius	–	–	–	–	C5–C6	–

Table 4. Range of brachial plexus in different phylogenetic groups compared with *Cavia porcellus*.

Order	Rodentia	Primates		Pilosa		Artiodactyla	Marsupial	Carnivora			
Family	Caviid	Callitrich	Atelid	Bradypo	Myrmecoph	Cervidae	Macropo	Muste	Canidae	Procyonid	Felidae

	ae	idae	ae	didae	agidae		didae	lids			ae			
Nerve	*Cavia porcellus* (Our study)	*C. jacchus* [23]	*A. guariba* [63]	*Bradypus variegatus* [45]	*M. atridactyla* [62]	*Mazama gouazoubira* [46, 71]	*N. rufogriseus* [11]	*M. foina* [21]	*A. microts* [54]	*V. vulpes* [34]	*Potos flavus* [24]	*N. nasua* [69]	*C. caracal* [33]	*P. concolor* [12]
BP range	**C6–T1 C5–T1 C6–T2**	**C5 (C4) –T1**	**C4–T2**	**C8–C9–C10–T1–T2**	**C5–C8**	**C6–T1**	**C4–T1**	**C6–T1**	**C6–T1**	**C6–T2 C6–T1 C5–T2**	**C5–T2**	**C5–T2**	**C6–T1**	**C6–T1**
Radialis	C6–T1	C6–T2	C5–T1 C4–T1 C6–C8	C8–T2	C5–T1	C7–C8	C6–T1	C8–T1	C7–C8	C7–T1 C7–T2	C6–T2 C7–T2	C6–T1	C7–T1	C7–T1
Axillaris	C6–C8	C5–T1	C5–C6 C5–C7 C6 C5–C7	C8–C9 C8–C10	C5–C7	C6–C7	C6–C7	C7	C6–C7	C6–C7	C6–C7 C6–C8 C7	C6–C7	C6–C7	C6–C7
Medianus	C7–T1	C6–T1	C5–C7 C6–T1 C5–T2	C8–T2	C5–T1	C7–C8	C6–T1	C8–T1	C7–T1	C8–T1	C6–T2	C6–T1 (T2)	C7–T1	C7–T1
Ulnaris	C8–T1 (C8–T2)	C6–T1	C8–T1 C8–T2	C10–T2 T1–T2	C5–T1	C8–T1	C8–T1	C8–T1	C8–T1	C8–T1 C8–T2	C8–T2	C8–T1 (T2)	C8–T1	C8–T1
Msculo	C6–	C5 (C4)	C5–	C8–T2	C5–C7	C6–C8	C6–C7	C7	C6–	C6–	C6–	C6–	C6–	C6–

cutaneus	C8 C5–C8	–C7	C6 C5–C7						C7	C7	C7	C7	C7	C7
Suprascapularis	C6–C7 C5–C7	C5 (C4) –C6	C5 C4–C5 C5–C6	C8 C8–C9	C5–C7 C5–C6	C6–C7	C4–C6	C6	C6–C7	C5–C7 C6–C7	C5–C6 C5–C7 C6–C7	C5–C6 C6 C6–C7	C6–C7	C6
Subscapularis	C6–C7 C6	C4–C7	C4–C5 C4–C7 C5–C6	C8 C8–C9 C8–C10	C5–C7	C6–C7	C5–C6	C6–C7	C6	C6–C7	C6 C6–C7 C7	C5–C7	C6–C7	C6–C7
Pectorales craniles	C6–C7	C7–T1	C5–C7 C6–C7	C8–C9 C8–C10 C10– T2	C5–C8 C5–C7	C8–T1	C6–C7	C7	C7–T1	C6–C7	C6–C7 C6–C8 C6–T2 C7	C6–C7 C7	C6–C7	C7
Pectorales caudales	C8–T1	C8–T1	C7–T1 C8–T1	C10– T2 T1–T2	C8–T1	C8–T1	C8–T1	C7–C8	C8–T1	C8–T1 C8–T2	C6–T2 C8 C8–T2	C7 (C6) –T1	C8–T1	T1
Thoracicus Longus	C6–C7	C6–C7	C5–C7 C7 C7–C8	C10	C6–C7 C5–C7	C7–C8	C8–T1	C7–C8	–	C7	C7	C6–C8	C7	C7
Thoracicus lateralis	C8–T1	–	–	C8–C9 C8–C10 C10–T2	C7–T1 C8–T1	C8–T1	C8–T1	C7–C8	–	T1–T2	C8–T2 C6–	C8(C7) –T1	C8–T1	T1

											T2			
Thpracodorsalis	C8–T1	C8–T1	C5–C7 C6–C8 C7–C8 C7–T1	C8–C10 C10 C8–T2	C5–C8 C5–C7	C7–C8	C6–C8	C7–C8	C8–T1	C7–C8	C6–T2 C6–C8 C7–T2 C8–T2	C7–C8	C7–C8	C7–C8
Brachiocephalicus	C6 C5–C6	–	–	–	–	–	–	–	–	C6	C5–C6 C6 C6–C7	C5–C6 C6	C6	–
Dorsalis scapulae	C5–C6 C6	C4–C5	–	–	–	–	–	–	–	–	–	–	–	–
Subclavius	C6	C4–C6	C5	–	–	–	–	C6		–	–	–	–	–

Table 5. Comparison of the innervation ranges of individual brachial plexus nerves in different rodent species.

Nerve	*Cavia porcellus* (Our study)	*Cavia porcellus [55]*	*Cavia porcellus [17]*	*Chinchilla lanigera* [28]	*Myocastor coypus* [66]	*Hydrochaeris hydrochaeris* [26]	*Sphingurus villosus* [25]	*Galea spixii* [5]	*H. cristata* [7]
Brachiocephalicus	plm	–	–	–	–		–	–	–
Dorsalis	rhmc,	–	rhm	–	rhm	rhm	–	–	–

scapulae	rhmcr, rhmt, srvc								
Subclavius	sbc, sccl	–	sbc, pcs	sbc	sbc	–	–	–	–
Suprascapularis	spsp, ifsp	spsp, ifsp	spsp, ifsp	spsp, ifsp, del (acromion)	spsp, ifsp	spsp, ifsp	spsp, ifsp	spsp, ifsp	spsp, ifsp
Subscapulares	sbs	Sbs, tma, latdo	sbs, tma	sbs	sbs, tma	sbs	sbs	sbs	sbs, tma
Axillaris	sbs, tma, tmi, del	not specified	ombr, del	sbs, tam, rmi, del	tmi, del	trbr	tma, tmi, del, bra, ifsp	sbs, tma, tmi, del	sbs, tma, tmi, del
Musculocutaneus	crb, bcbr, bra, skin of the antebrachium (medial face)	bcbr, skin of the antebrachium (medial face)	–	bcbr, bra	crb, bra, bcbr	–	crb, bcbr,	crb, bra, bcbr	bra
Pectorales craniales	pcs	pcs	pcs, ombr, pcp	pcs	pcs	–	pcs	pcs	pcs, pcp
Radialis	tfab, trbr, bhr, sup, ecrl, ecrb, edc, edl, ecu, anc, apl, ed1	not specified	trbr, tfab, anc	trbr, ecrl, ecrb, edc, edl, ecu, supl, supb	trbr, tfab, can, ecrl, ecrb, sup, edc, edqp, apl, ecu	trbr, anc, ecr, edc, edl	Ecr, edc prte	bra, ecrl, trbr, tfab, fd2, fd3	trbr, tfab extensor muscles on antebrachium, ecr
Medianus	prte, fcr, fdp, prq, fds, pml	not specified	prte, fcr, bra, fdp, fds, pml, cbr,	fcr, prte, fd3, fd4	fds, fdp, prte, fcr, prq	bcbr,fcr,crb, bra	fcr, fds	fcr, prte, fd3, fd4	not specified

			bcbr, fdpb, digiti II, III, IV, skin palmar face, apl						
Ulnaris	fcu, eptac, fdp	not specified	fdp, fds, fcu,	fcu, int, fdp	pml, fcu, fdp, eptac	ecr, fcu, fds	ecu, fdp	eptac, int, fcu, fd5	not specified
Thoracodorsalis	latdo	–	latdo	latdo	latdo	latdo	latdo	latdo	latdo
Thoracicus lateralis	cuttr	–	cuttr, pcp	cuttr	–	cuttr, pcp	cuttr	cuttr	pcp, ombr
Thoracicus longus	srvt	srvt, scn	srvt	srvt	srvt	srvt	srvt	srvt	–
Pectorales caudales	pcp	pcp	–	–	pcp, scn, cuttr	–	pcp	pcp	cuttr, pcp

apl — abductor pollicis longus; anc — anconeus; bcbr — m. biceps brachii; bra — m. brachialis; bhr — m. brachioradialis; crb — m. coracobrachialis; cuttr — m. cutaneus trunci; del — m. deltoideus; eptac — m. epitrochleoanconeus; ecr — m. extensor carpi radialis; ecrb — m. extensor carpi radialis brevis; ecrl — m. extensor carpi radialis longus; ecu — m. extensor carpi ulnaris; ed1 — m. extensor digiti I; edc — m. extensor digitorum communis; edl — m. extensor digitorum lateralis; edqp — m. Extensor digiti quir'ti proprius; fcr — m. flexor carpi radialis; fcu — m. flexor carpi ulnaris; fd2 — m. flexor digiti II; fd3 — m. flexor digiti III; fd4 — m. flexor digiti IV; fd5 — m. flexor digiti V; fdp — m. flexor digitorum profundus; fdpb — m. flexor digitorum profundus; fds — m. flexor digitorum superficialis; int — m. interossei; ifsp — m. infraspinatus; latdo — m. latissimus dorsi; ombr — m. omobrachialis; pcp — m. pectorales profundus; pcs — Mm. pectorales superficiales; plm — m. platysma; prq — m. pronator quadratus; prte — m. pronator teres; rhm — m. rhomboideus; rhmc — m. rhomboideus capitis; rhmcr — m. rhomboideus cervicis; rhmt — m. rhomboideus thoracis; scn — m. scalenus; sccl — m. scapulocalvicularis; srvc — m.

serratus ventralis cervicis; srvt — m. serratus ventralis thoracis; sbc — m. subclavius; sbs — m. subscapularis; sup — m. supinator; supb — m. supinator brevis; supl — m. supinator longus; spsp — m. supraspinatus; tma — m. teres major; tmi — m. teres minor; tfab — m. tensor fasciae anbrachii; trbr — m. triceps brachii.

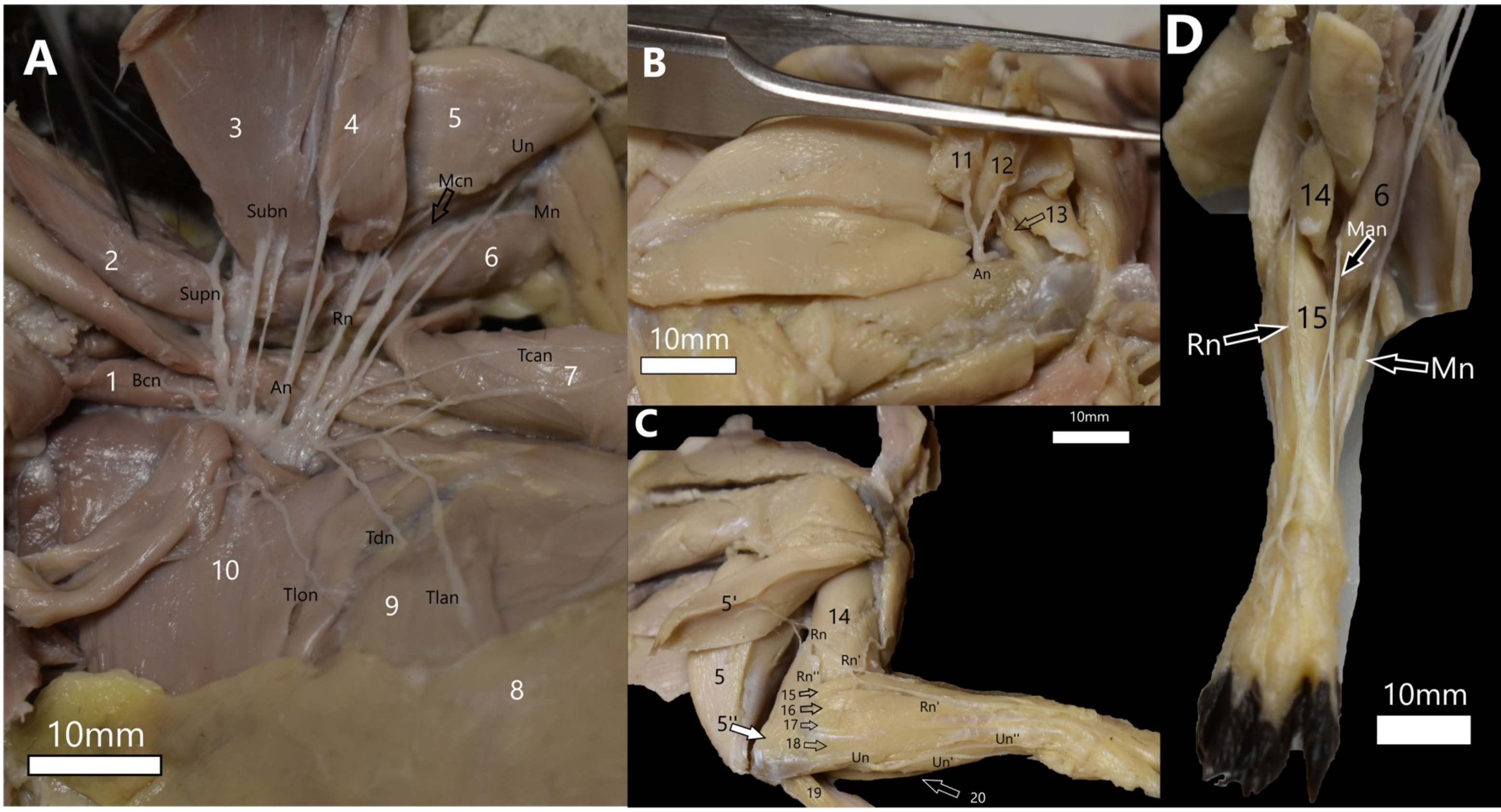


Figure 1. Photographic representations of the brachial plexus and its nerves in the guinea pig (*Cavia porcellus*). **A.** Individual nerves coming out of the brachial plexus (right thoracic limb, medial view); **B.** The course of the axillary nerve on the lateral side of the scapula (right thoracic limb, lateral view); **C.** The course of the radial and ulnar nerves on the lateral side of

the antebrachium (right thoracic limb, lateral view); **D.** The course of the radial, medial antebrachial cutaneous and median nerves on the dorsal and medial sides of the antebrachium (right thoracic limb, dorsal view). Muscles: 1 — m. cleidocephalicus (separated); 2 — m. supraspinatus (separated); 3 — m. subscapularis; 4 — m. teres major; 5 — caput longum of the m. triceps brachii; 5' — caput laterale of the m. triceps brachii; 5" — caput mediale of the m. triceps brachii; 6 — m. biceps brachii; 7 — mm. pectorales profundus; 8 — m. cutaneus trunci; 9 — m. latissimus dorsi; 10 — m. serratus ventralis thoracis; 11 — m. deltoideus (acromion part); 12 — m. deltoideus (scapularis muscle); 13 — m. teres minor; 14 — m. brachialis; 15 — m. extensor carpi radialis; 16 — m. extensor digitorum communis; 17 — m. extensor digitorum lateralis; 18 — m. extensor carpi ulnaris; 19 — m. flexor carpi ulnaris; 20 — m. flexor digitorum profundus. Abbreviations: An — n. axillaris; Bcn — n. brachiocephalicus; Mcn — n. musculocutaneus; Mn — n. medianus; Rn — n. radialis; Rn' — r. superficialis (n. radialis); Rn" — r. profundus (n. radialis); Subn — nn. subscapulares; Supn — n. suprascapularis; Tcan — nn. Pectorales caudales; Tdn — n. thoracodorsalis; Tlan — n. thoracicus lateralis; Tlon — n. thoracicus longus; Un — n. ulnaris; Un' — r. palmaris (n. ulnaris); Un" — r. dorsalis (n. ulnaris); Man — n. cutaneus antebrachii medialis.

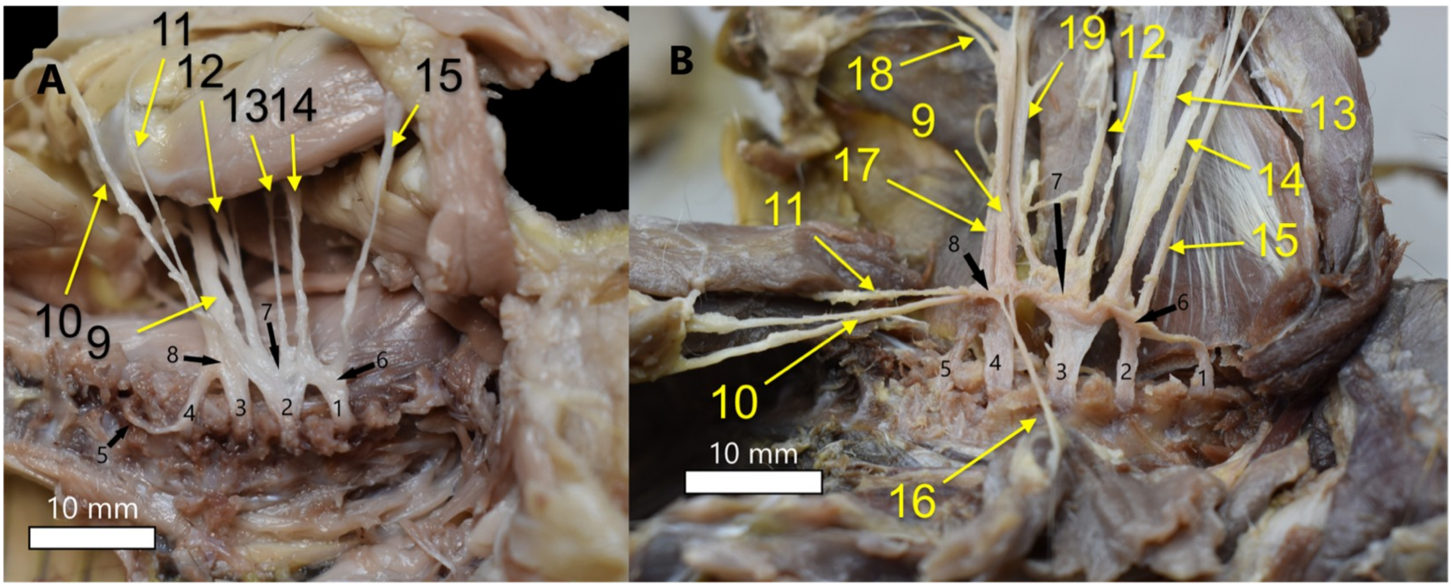


Figure 2. Brachial plexus composed of C6–T2. **A.** Right-side plexus, medial view and C5–T1. 1 — C6; 2 — C7; 3 — C8; 4 — T1; 5 — T2; 6 — cranial trunk; 7 — middle trunk; 8 — caudal trunk; 9 — n. medianus; 10 — n. thoracicus lateralis; 11 — nn. pectorales caudales; 12

— n. axillaris; 13 — nn. subscapulares; 14 — n. suprascapularis; 15 — n. brachiocephalicus. **B.** Right-side plexus, medial view. 1 — C5; 2 — C6; 3 — C7; 4 — C8; 5 — T1; 6 — cranial trunk; 7 — middle trunk; 8 — Caudal trunk; 9 — n. medianus; 10 — n. thoracicus lateralis; 11 — nn. pectorales caudales; 12 — n. axillaris; 13 — nn. subscapulares; 14 — n. suprascapularis; 15 — n. brachiocephalicus; 16 — nn. pectorales craniales; 17 — n. ulnaris; 18 — n. n. cutaneus antebrachii caudalis; 19 — n. radialis.

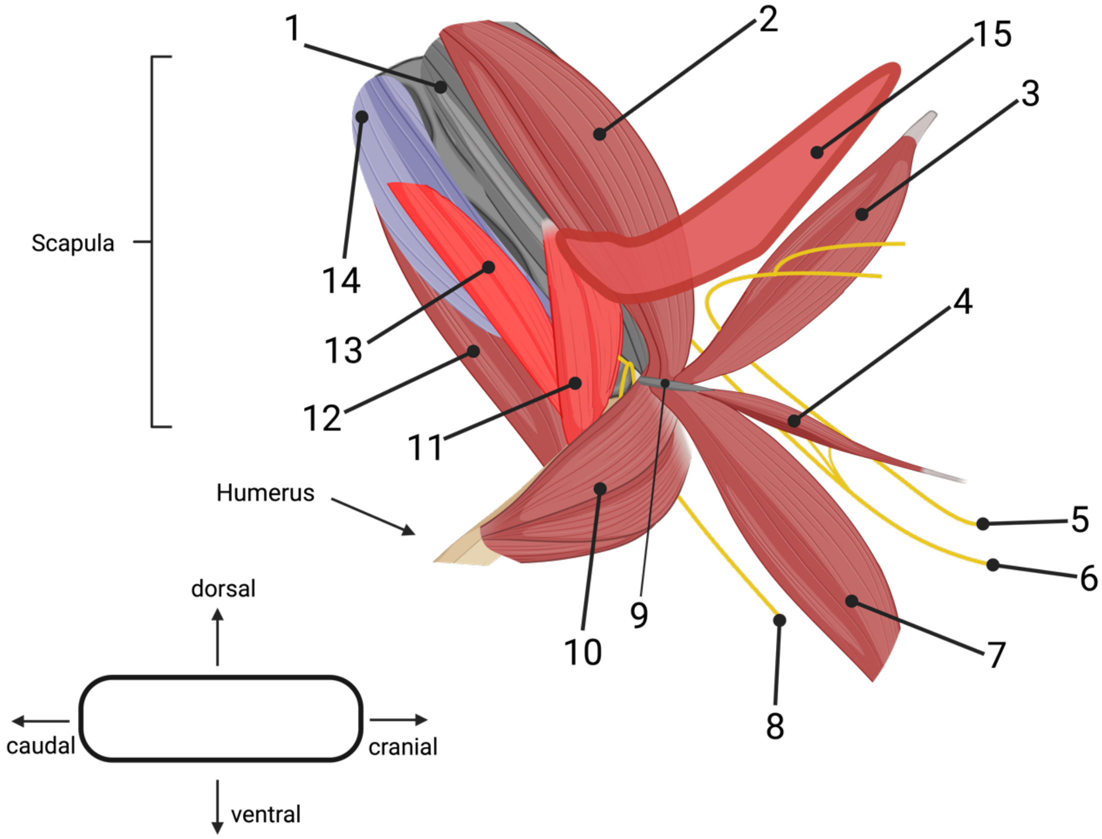


Figure 3. Diagram of the brachiocephalic muscle arrangement in the guinea pig and schematic of the n. brachiocephalicus, n. subclavius, and n. axillaris (right thoracic limb, lateral view). 1 — m. supraspinatus; 2 — m. scapuloclavicularis; 3 — m. brachiocephalicus; 4 — m. subclavius; 5 — n. brachiocephalicus; 6 — n. subclavius; 7 — m. pectorales caudales; 8 — n. axillaris; 9 — Intersectio clavicularis; 10 — m. cleidobrachialis; 11 — m. deltoideus (pars acromialis); 12 — m. teres major; 13 — m. deltoideus (pars scapularis); 14 — m. infraspinatus; 15 — m. omotransversarius.

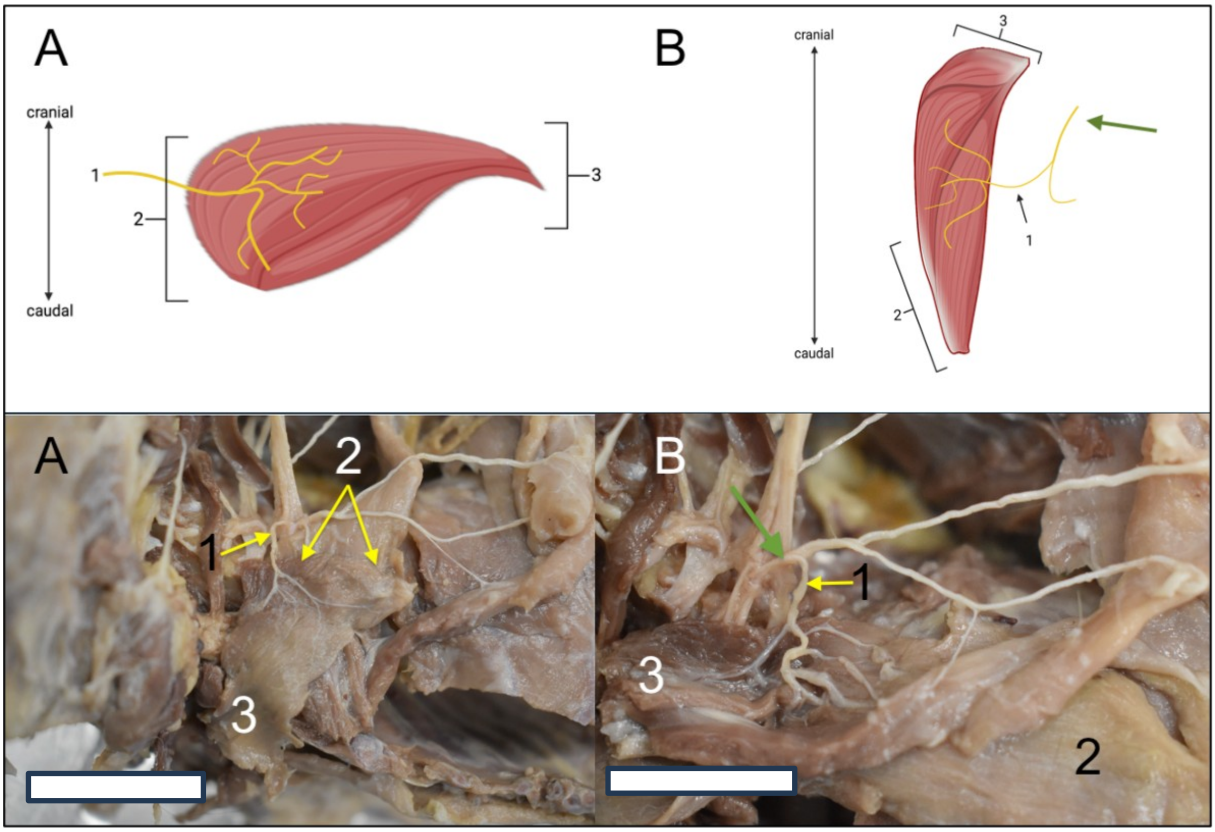


Figure 4. Diagram and photos showing the distribution of nerves (right-side pectoral nerves, medial view): perctoralis cranialis (**A**) and pectorales caudales (**B**). 1 — nn. pectorales craniales/nn. pectorales caudales; 2 — sternal attachment of the muscle; 3 — humeral attachment of the muscle. Green arrow — the common trunk of the n. thoracicus lateralis and nn. pectorales caudales. Bar = 10 mm.

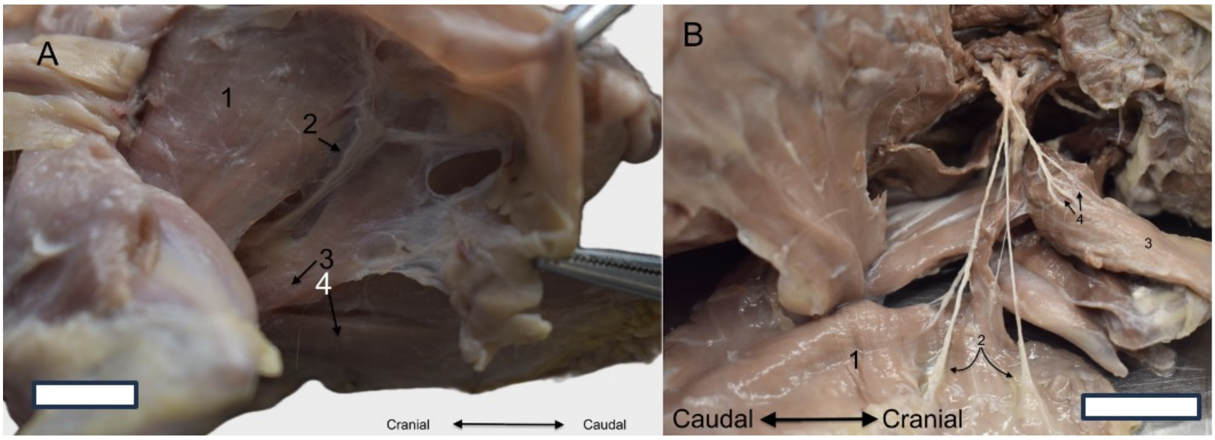
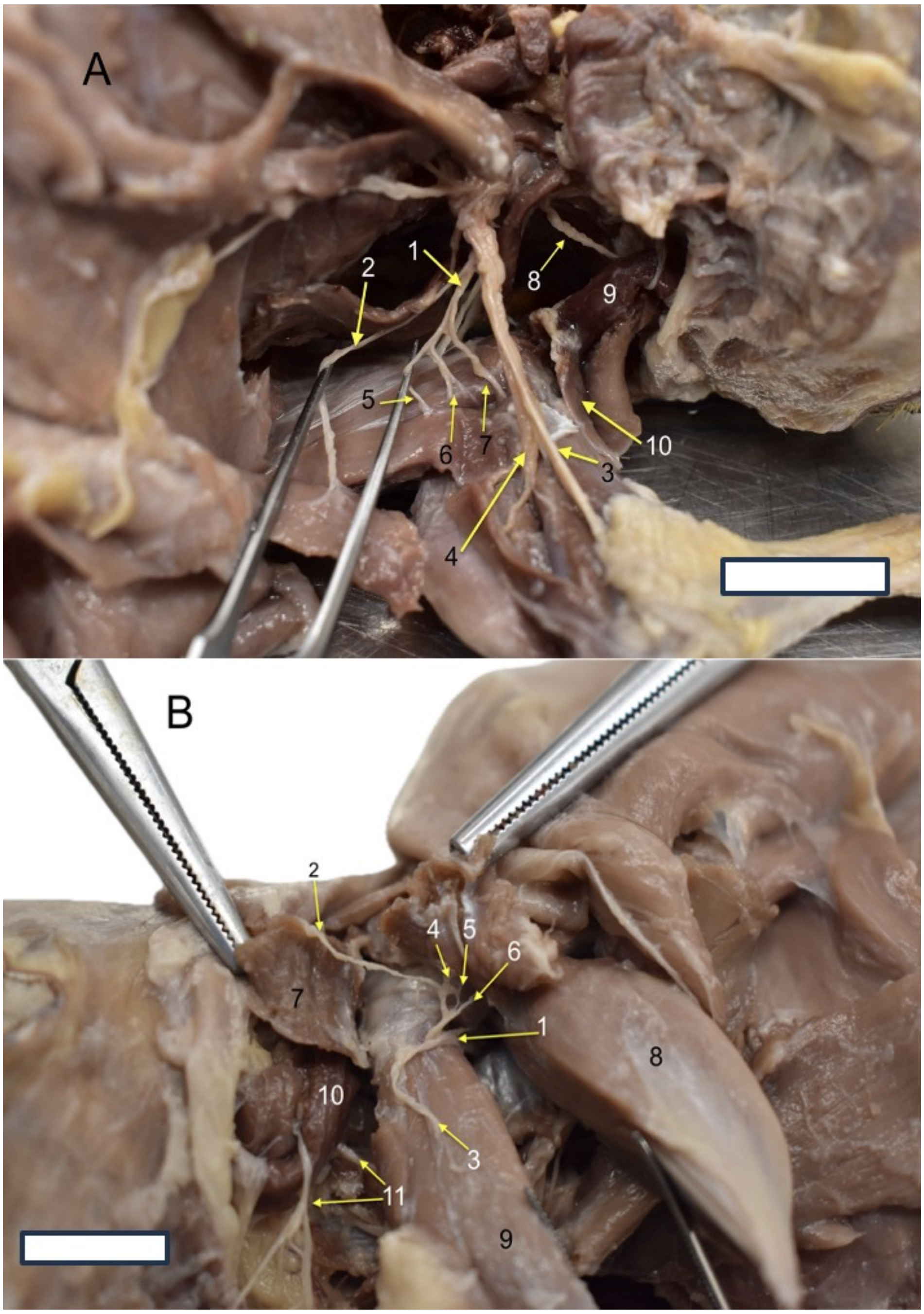


Figure 5. The lateral thoracic nerve exiting from between the thoracic muscles (**A**) and branching between the fibers of the m. cutaneus trunci (**B**). In addition, the nn. pectorales caudales emerging from a common trunk with the n. thoracicus lateralis are also shown. Photo A (left thoracic limb, lateral view): 1 — m. latissimus dorsi; 2 — n. thoracicus lateralis; 3 — m. cutaneus trunci; 4 — mm. pectorales profundus. Photo B (left thoracic limb, medial view): 1 — m. cutaneus trunci; 2 — n. thoracicus lateralis; 3 — mm. pectorales profundus; 4 — nn. pectorales caudales. Bar = 10 mm.


A
1
2
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9
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3
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B
2
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11
9

Figure 6. Course, extent of innervation, and topographical relations of the n. axillaris. **A.** Medial side. **B.** Lateral side. Photo A (left thoracic limb, medial view): 1 — n. axillaris; 2 — n. thoracodorsalis; 3 — n. medianus; 4 — n. radialis; 5 — muscular branch of the n. axillaris to m. teres major; 6 — muscular branch of the n. axillaris to m. subscapularis; 7 — n. axillaris running to the quadrangular space; 8 — n. brachiocephalicus; 9 — m. brachiocephalicus (cleidocephalicus); 10 — brachiocephalicus (cleidobrachialis)/m. deltoideus pars clavicularis. Photo B (left thoracic limb, lateral view): 1 — n. axillaris; 2 — muscular branch to m. cleidobrachialis; 3 — n. cutaneus brachii lateralis cranialis; 4 — muscular branch to m. deltoideus pars acromialis; 5 — muscular branch to m. deltoideus pars scapularis; 6 — muscular branch to m. teres minor; 7 — m. cleidobrachialis; 8 — caput longum m. triceps brachii; 9 — caput laterale m. triceps brachii; 10 — m. brachiocephalicus (cleidocephalicus); 11 — n. brachiocephalicus. Bar = 10 mm.

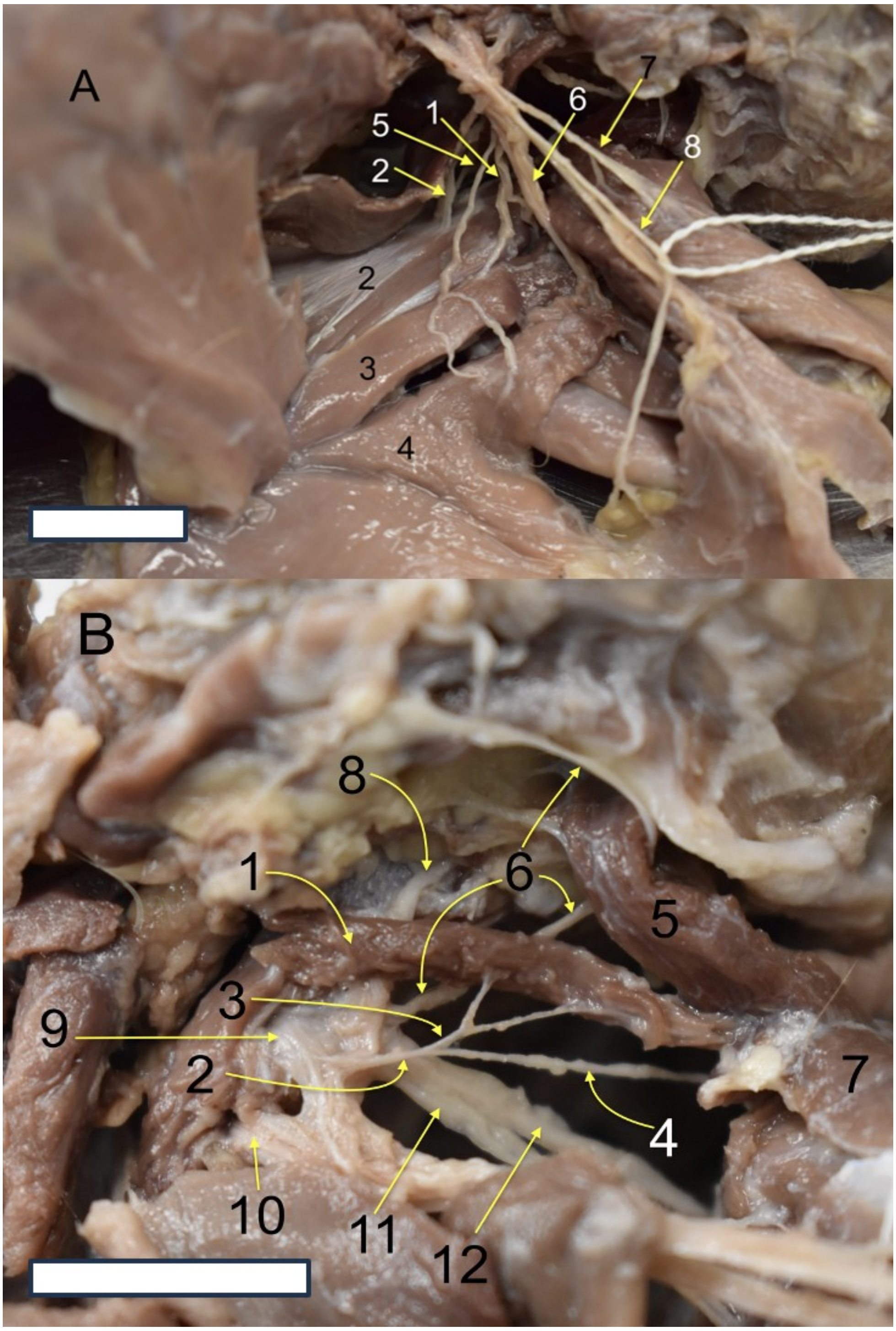

Figure 7. Course, extent of innervation, and topographical relations of the n. thoracodorsalis (**A**; left thoracic limb, medial view) and n. subclavius (**B**; left-side plexus, medial view). Photo A: 1 — n. axillaris; 2 (white) — nn. subscapulares; 2 (black) — m. subscapularis; 3 — m. teres major; 4 — m. latissimus dorsi; 5 — n. thoracodorsalis; 6 — n. radialis; 7 — nn. pectorales caudales; 8 — n. thoracicus lateralis. Photo B: 1 — m. subclavius (cut); 2 — n. subclavius; 3 — muscular branch of the n. subclavius to m. subclavius; 4 — muscular branch of the n. subclavius to m. scapuloclavicularis; 5 — m. brachiocephalicus; 6 — n.

brachiocephalicus; 7 — m. cleidobrachialis; 8 — ramus communicans from ventral branch C5; 9 — C7; 10 — C8; 11 — nn. subscapulares; 12 — n. suprascapularis. Bar = 10 mm.

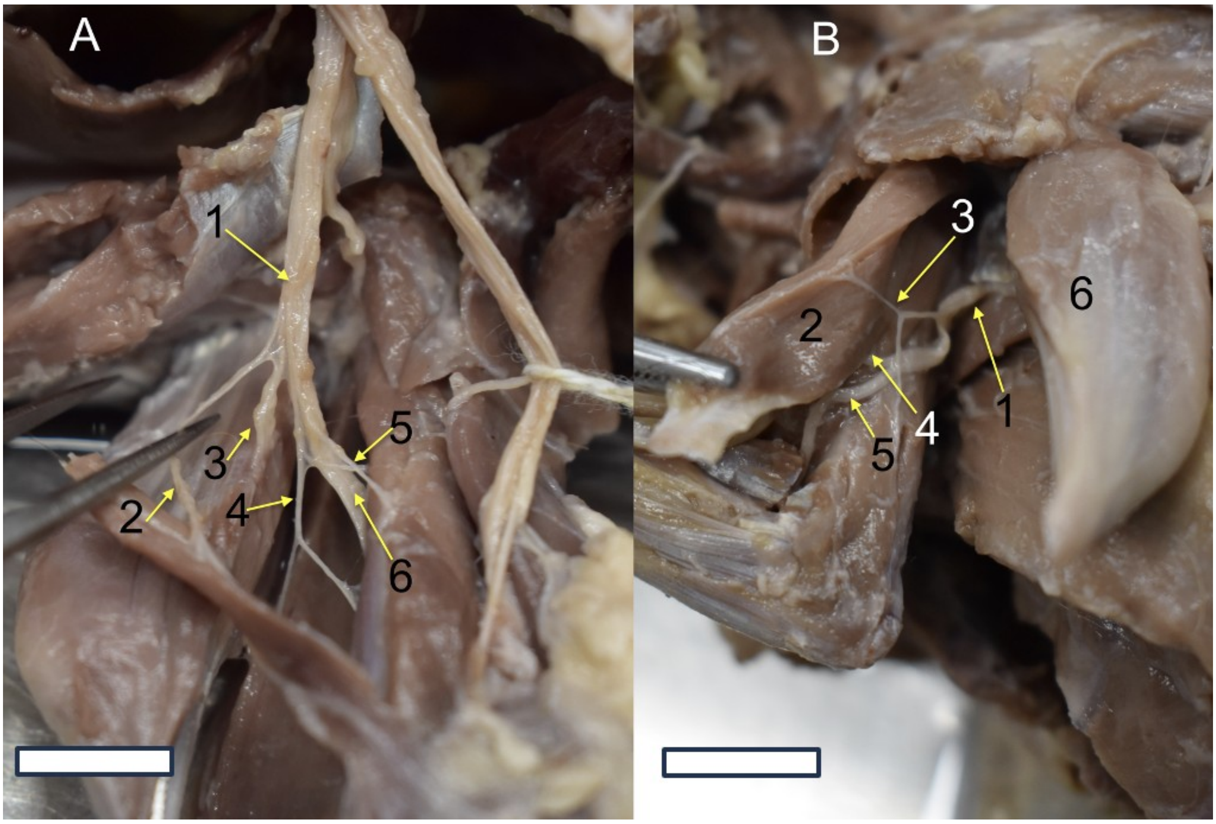

Figure 8. Course, extent of innervation, and topographical relations of the n. radialis. **A.** Left thoracic limb, medial view. 1 — n. radialis; 2 — muscular branch to m. tensor fasciae antebrachia; 3 — muscular branch to caput longum of the m. triceps brachii; 4 — muscular branch to caput laterale of the m. triceps brachii; 5 — muscular branch to caput mediale of the m. triceps brachii, n. radialis. **B.** Left thoracic limb, lateral view. 1 — n. axillaris; 2 — caput laterale of the m. triceps brachii; 3 — muscular branch to the caput laterale of the m. triceps brachii; 4 — ramus superficialis of the n. radialis; 5 — ramus profundus of the n. radialis; 6 — caput longum of the m. triceps brachii. Bar = 10 mm.

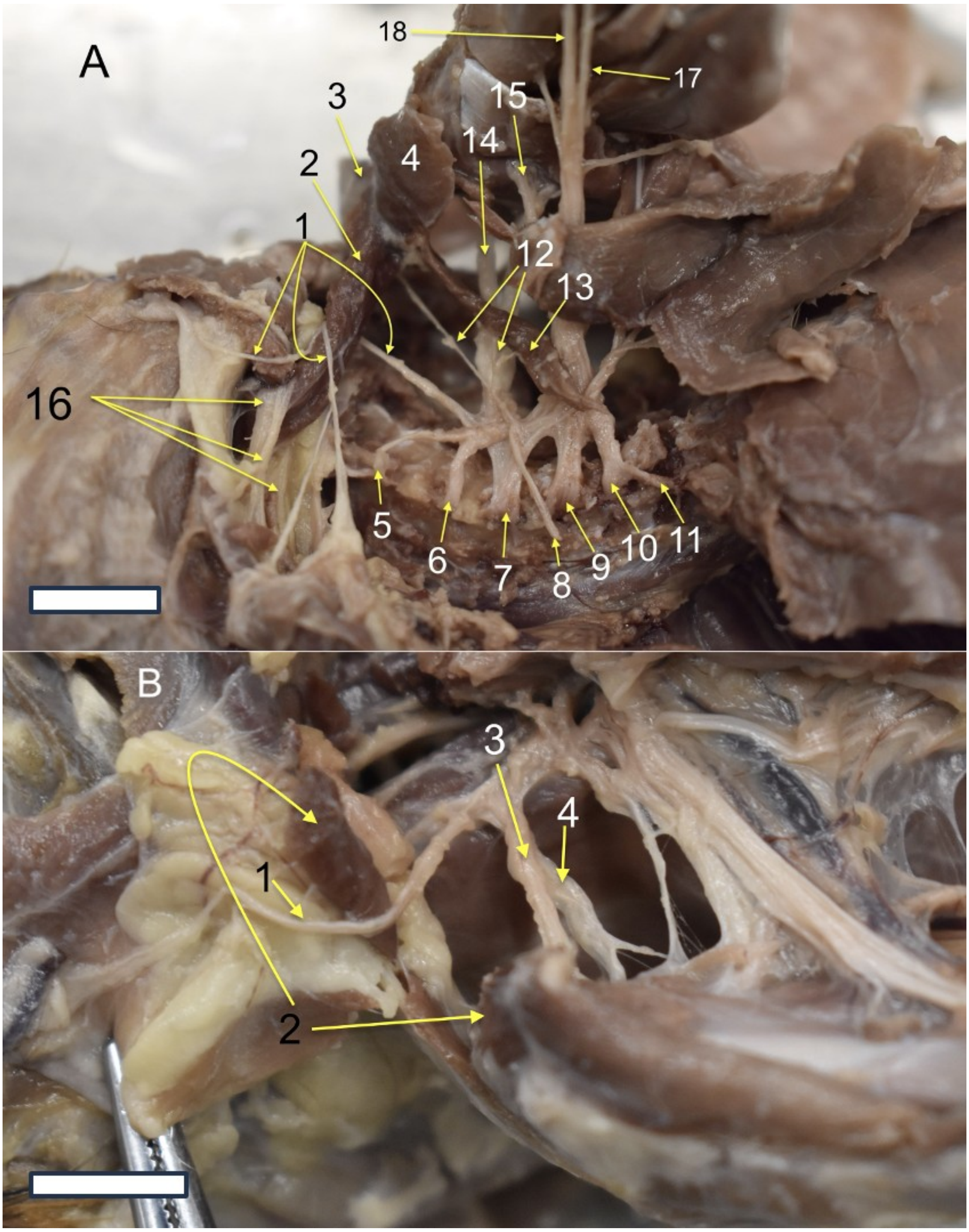

Figure 9. Course, extent of innervation, and topographical relations of the n. brachiocephalicus. **A.** Left thoracic limb, medial view. 1 — n. brachiocephalicus; 2 — m. brachiocephalicus (cleidocephalicus); 3 — m. scapuloclavicularis; 4 — m. cleidobrachialis; 5 — C5; 6 — C6; 7 — C7; 8 — n. phrenicus; 9 — C8; 10 — T1; 11 — T2; 12 — muscular branch of the n. subclavius; 13 — m. subclavius (cut in sternal attachment); 14 — n. suprascapularis; 15 — n. axillaris; 16 — nerves from cervical plexus; 17 — n. ulnaris; 18 —

n. medianus. **B.** Right thoracic limb, medial view. 1 — n. brachiocephalicus; 2 — m. brachiocephalicus (cut); 3 — n. suprascapularis; 4 — nn. subscapulares. Bar = 10 mm.

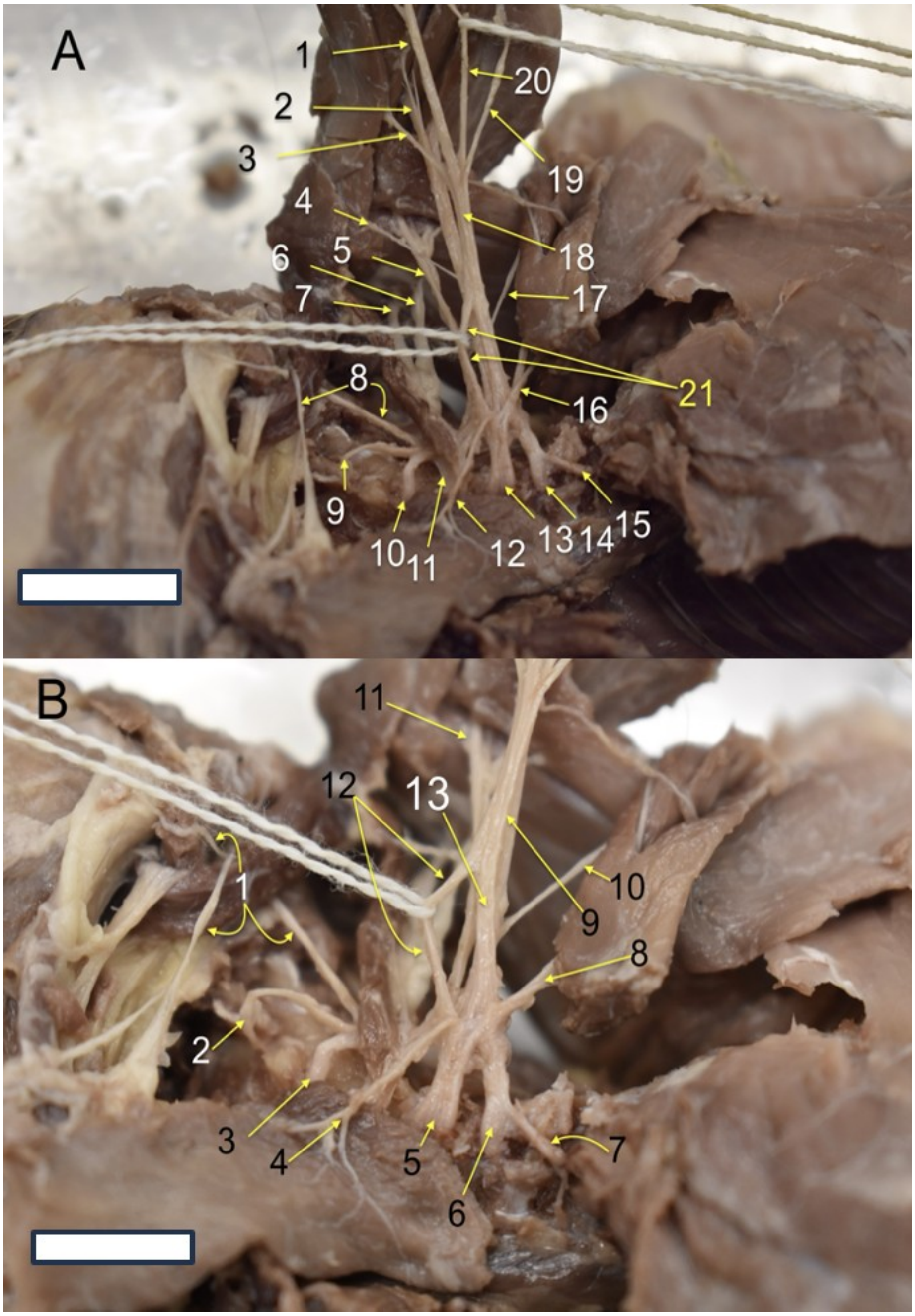

Figure 10. The brachial plexus of the guinea pig with a special presentation of the common trunk of the n. musculocutaneus, n. medianus, and n. ulnaris. **A.** Left thoracic limb, medial view. 1 — n. medianus; 2 — n. radialis; 3 — muscular branch to m. biceps brachii; 4 — muscular branch to m. coracobrachialis; 5 — n. axillaris; 6 — nn. subscapulares; 7 — suprascapularis; 8 — n. brachiocephalicus; 9 — C5; 10 — C6; 11 — C7; 12 — nn. pectorales craniales; 13 — C8; 14 — T1; 15 — T2; 16 — common trunk of the nn. pectorales caudales

and n. thoracicus lateralis; 17 — n. thoracodorsalis; 18 — common trunk of the n. musculocutaneus, medianus, and ulnaris; 19 — n. cutaneus antebrachii caudalis; 20 — n. ulnaris; 21 — n. musculocutaneus. **B.** Left thoracic limb, medial view): 1 — n. brachiocephalicus; 2 — C5; 3 — C6; 4 — nn. pectorales craniales; 5 — C8; 6 — T1; 7 — T2; 8 — common trunk of the nn. pectorales caudales and n. thoracicus lateralis; 9 — common trunk of the n. musculocutaneus, medianus, and ulnaris; 10 — n. thoracodorsalis; 11 — n. axillaris; 12 — n. musculocutaneus; 13 — common trunk of the n. medianus and n. ulnaris. Bar = 10 mm.

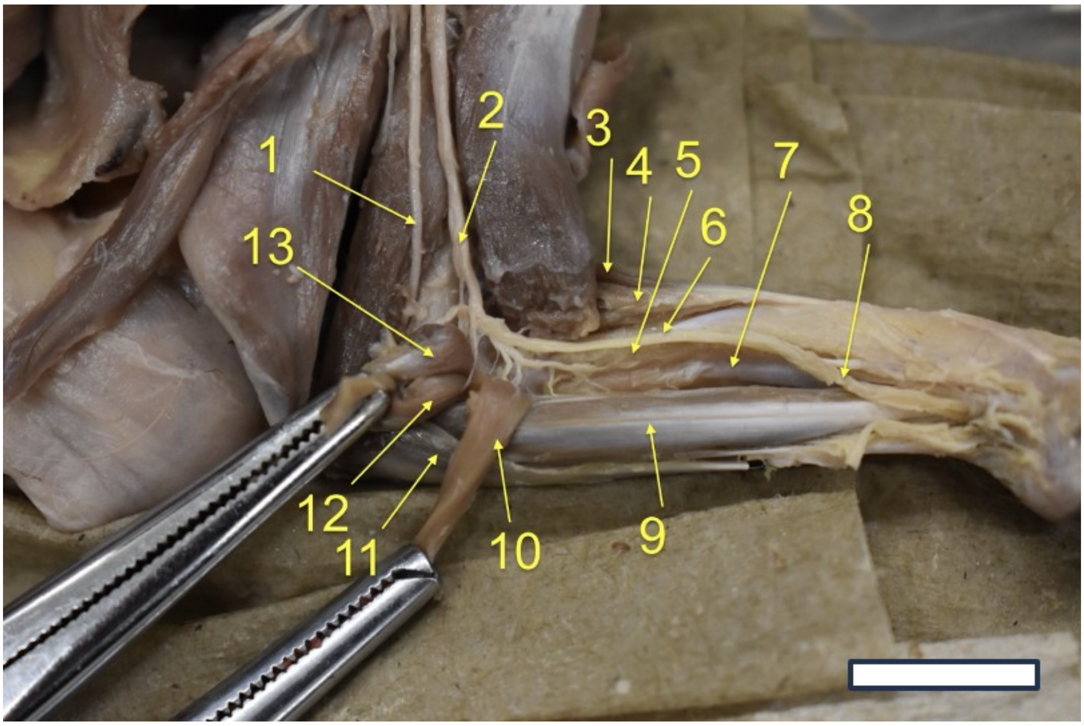

Figure 11. Course, extent of innervation, and topographical relations of the n. medianus on the antebrachium (left thoracic limb, medial view). 1 — n. ulnaris; 2 and 6 — n. medianus; 3 — m. brachioradialis; 4 — m. extensor carpi radialis; 5 — m. pronator quadratus; 7 — m. flexor digitorum profundus; 8 — the place where the n. medianus exits the flexor surface of the arm; 9 — m. flexor digitorum superficialis; 10 — m. palmaris longus; 11 — m. flexor carpi ulnaris; 12 — m. flexor carpi radialis; 13 — m. pronator teres. Bar = 10 mm.

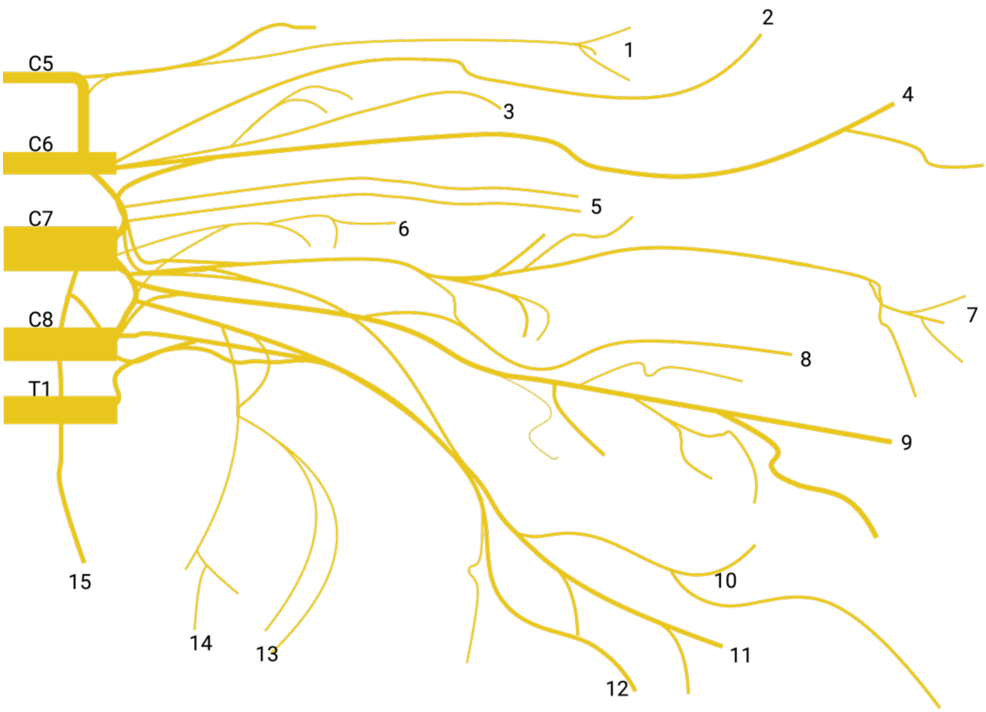

Figure 12. Diagram of the brachial plexus of the guinea pig with a range of C5–T1 (left limb, medial view). 1 — n. dorsalis scapulae; 2 — n. brachiocephalicus; 3 — n. subclavius; 4 — n. suprascapularis; 5 — nn. subscapulares; 6 — nn. pectorales craniales; 7 — n. axillaris; 8 — n. thoracodorsalis; 9 — n. radialis; 10 — n. musculocutaneus; 11 — n. medianus; 12 — n. ulnaris; 13 — n. thoracicus lateralis; 14 — nn. pectorales caudales; 15 — n. thoracicus longus. Bar = 10 mm.

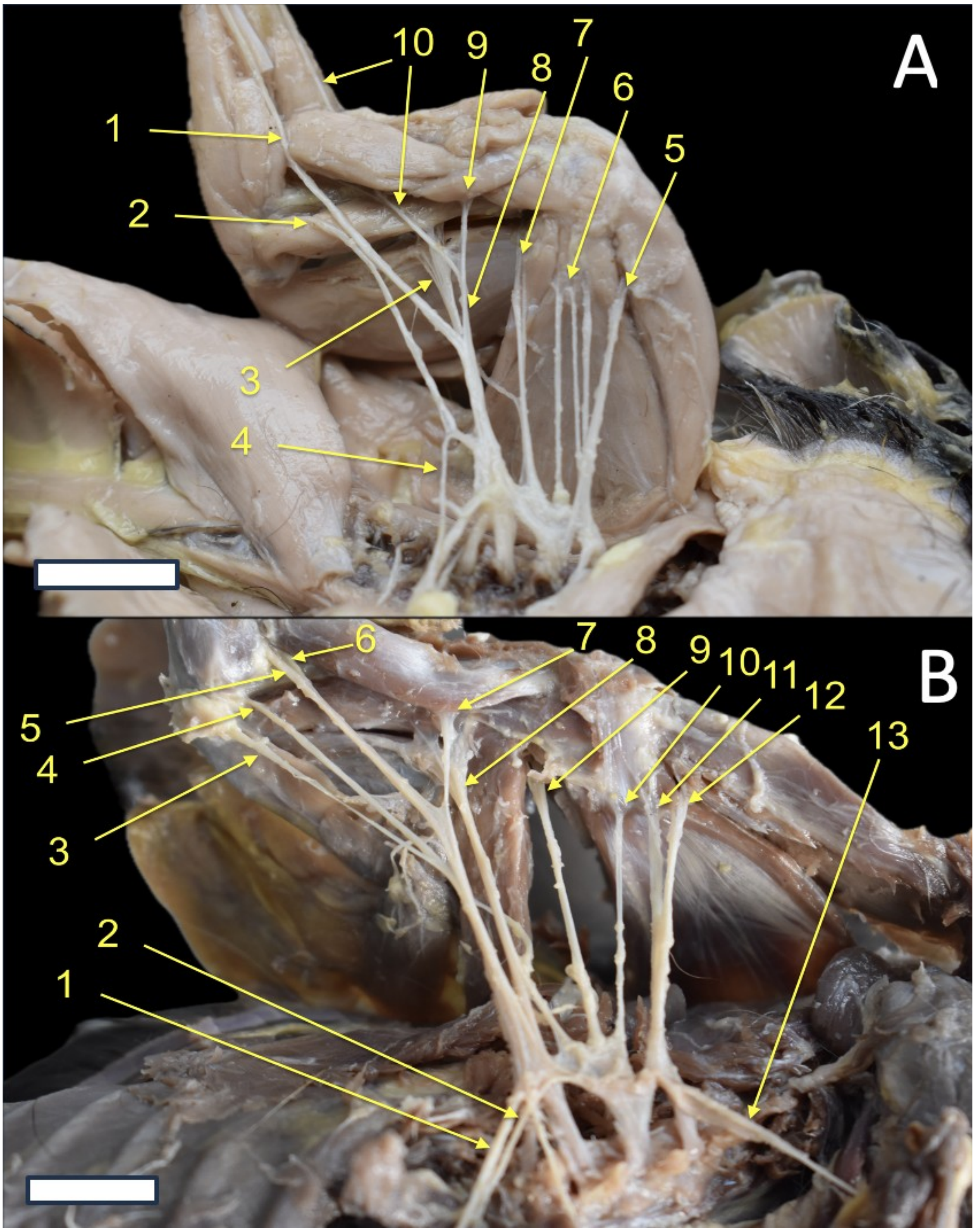

Figure 13. View of the brachial plexus with different connections between n. musculocutaneus and n. medianus. **A.** Right thoracic limb, medial view. The connection is shorter and the n. cutaneus antebrachii medialis is a direct extension of the n. musculocutaneus. 1 — n. medianus; 2 — n. ulnaris; 3 — n. radialis; 4 — n. cutaneus antebrachii caudalis; 5 — n. suprascapularis; 6 — nn. subscapulares; 7 — n. axillaris; 8 — n. musculocutaneus; 9 — muscular branch to m. biceps brachii; 10 — n. cutaneus antebrachii medialis. **B.** Right thoracic limb, medial view. The junction is longer and the n. cutaneus antebrachii medialis and the musculocutane branch to m. biceps brachii diverge from the

common portion of the n. musculocutaneus and n. medianus. 1 — n. thoracicus lateralis; 2 — nn. pectorales caudales; 3 — n. cutaneus antebrachii caudalis; 4 — n. ulnaris; 5 — n. medialis; 6 — n. cutaneus antebrachii medialis; 7 — muscular branch to m. biceps brachii; 8 — n. radialis; 9 — n. axillaris; 10 — muscular branch to m. subscapularis; 11 — nn. subscapulares; 12 — n. suprascapularis; 13 — brachiocephalicus. Bar = 10 mm.

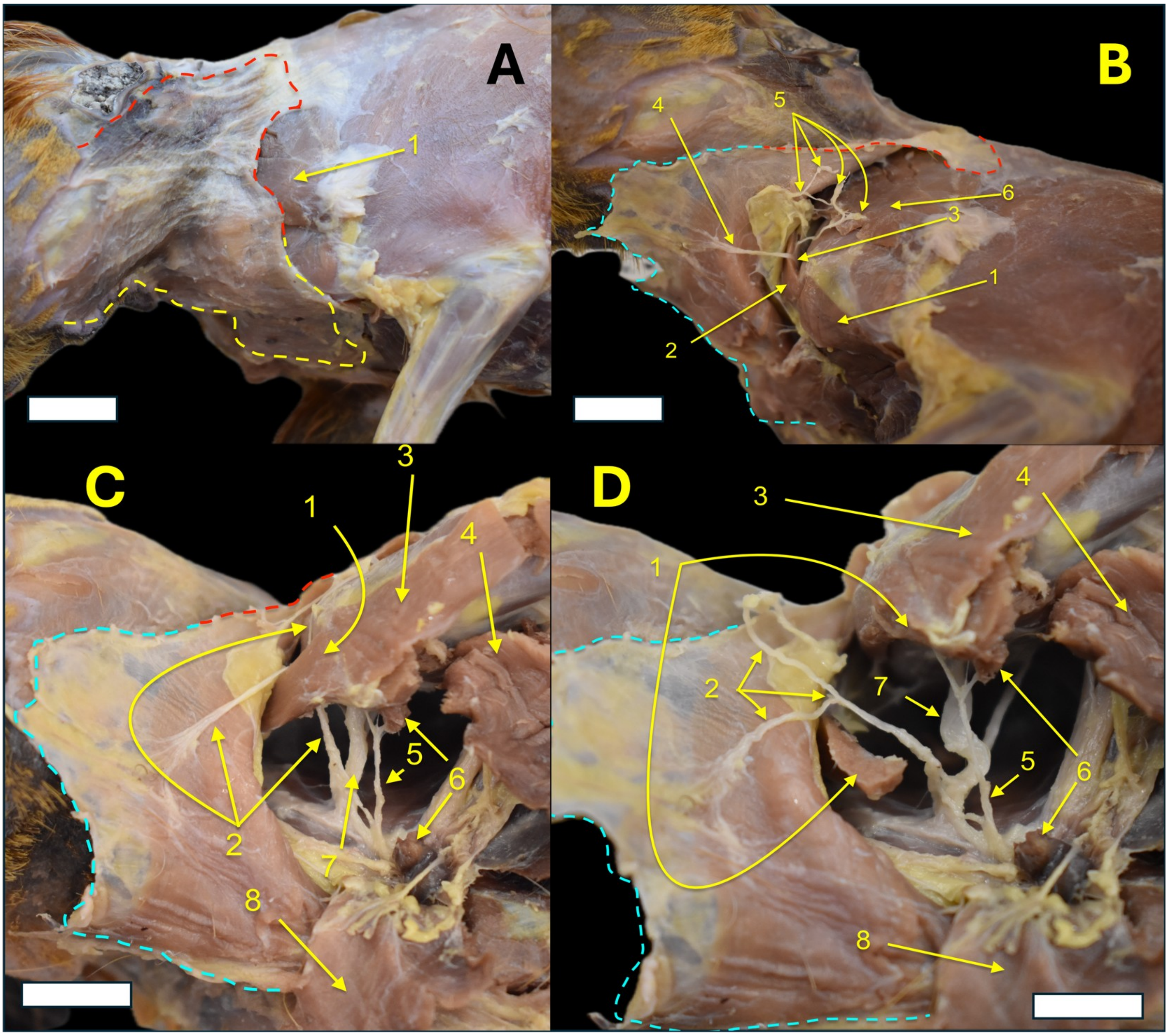

Figure 14. View of m. plastysma and the course of n. brachiocephalicus with its branching into m. platysma. **A.** Red outline — m. platysma thoracic part; yellow outline — m. platysma cervical part; 1 — m. omotransversarius. **B.** Retracted m. platysma. Blue outline — m. platysma cervical part; red line — m. platysma thoracic part; 1 — m. cleidobrachialis; 2 — m. cleidocephalicus; 3, 4, and 5 — n. brachiocephaliscus; 6 — m. omotransvesarius. **C.** Retracted platysma and pectoralis superficialis muscles; cut subclavius and pectorales profundus muscles). **D.** Retracted platysma and superficial pectoral muscles; cut subclavian, pectorales profundus, and cleidocephalic muscles. Blue outline—m. platysma, cervical part; red outline — m. platysma, thoracic part; 1 — cleidocephalicus; 2 — n. brachiocephalicus; 3

— m. cleidobrachialis; 4 — mm. pectorales profundus; 5 — n. subclavius; 6 — m. subclavius; 7 — n. suprascapularis; 8 — mm. pectorales superficiales.