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CELLULAR AND MOLECULAR BIOLOGY

Origin and insertion of the nerves constituting the braquial plexus of the roadside hawk

DEREK L. MACHADO, THIAGO LEZARDO, JULIANA P. GUIMARÃES, NAIANNE K. CLEBIS & KARINA M. GAGLIARDO

Abstract: The roadside hawk (*Rupornis magnirostris*) is a free-living bird that commonly has wing injuries caused by man-made obstacles when flying. Studies that describe the topographic anatomy of the wings of this species are necessary to assist in the treatment of possible wing lesions. For this reason, the present work aimed to describe the origin and insertion of the nerves that constitute the brachial plexus in roadside hawks. Five roadside hawk carcasses donated to the Animal Anatomy Laboratory of the São Judas University Center, UNIMONTE campus, by *CEPTAS* (Center for Research and Screening of Wild Animals) were used for the study. The brachial plexus of the roadside hawk was formed by the union of the ventral branches of the spinal nerves located between C9-C10-T1-T2-T3. The ventral branches joined together and formed four short trunks which later united again by exchanging nerve fibers and constituting a big caliber branch. This is divided into two nerve cords (dorsal and ventral) which are destined to specific muscular groupings. The dorsal cord originates the axillary, anconeal and radial nerves, and is responsible for innervating the extensor muscles. The ventral cord originates the pectoral, bicipital, median-ulnar, median and ulnar nerves, and is responsible for innervating the flexor muscles.

Key words: *Rupornis magnirostris,* wing, Brachial Plexus, anatomy, birds.

INTRODUCTION

The great diversity of Brazilian territory (flora and fauna) allows the existence of a large number of taxonomic groups (ICMBIO 2018). The roadside hawk (*Rupornis magnirostris*), also known by the names of anajé, indaié-hawk, inajé, ripino, indaié and pega-pinto, is a bird of the *accipitridae* family observed from Mexico to Argentina. It is classified as a bird of prey, meaning a carnivorous bird that presents certain adaptations for active hunting (Santos & Rosado 2009, Santos et al. 2009). It is not currently considered endangered according to the International Union for Conservation of Nature (IUCN 2018), being the most abundant and well-distributed hawk in Brazil (Sick 1997).

The roadside hawk is characterized by a sharp and curved beak, well-developed and strong claws, as well as excellent vision and hearing, giving this animal hunting ability (Brown 1997, Silva 2016). It presents a great variation in its plumage colors according to the region of the country. However, it stands out for its finely bared chest of the belly and the tail with several clear stripes in contrast to the dark gray bands or black. Males and females are practically the same except in relation to size, with the female being larger. It feeds on large insects, lizards, small snakes, birds such as ground doves and sparrows, and can also catch bats in daytime landings (Robinson 1994, Sick 1997).

Exacerbated anthropic activity promotes changes in the biome, promoting the destruction of several habitats (Ramos et al. 2011). Free-living birds such as the roadside hawk are often susceptible to injury due to accidents with human-imposed obstacles (ICMBio 2018, Ministério do Meio Ambiente 2003). Thus, complex structures of the wings like the nerves that constitute the brachial plexus become compromised, preventing their flight and consequently excluding them from their habitat.

Wing muscles are innervated by nerves coming from the brachial plexus. The nerve roots (origin of the nerves) pass through the lateral cervical musculature and are suddenly found to form the trunks of the brachial plexus. Most branches from the trunks are ventrally viewed from the scapula and caudally to the humerus (Baumel 1986, Brenner et al. 2010, Dyce et al. 2010). The study of the brachial plexus is extremely important for early diagnosis of diseases that affect the brachial plexus (Shell et al. 1993), as well as for adequate therapeutic management for both surgical repair of wing fractures (Gizah et al. 2008) and for the anesthetic protocols in this region (Soresini et al. 2013). For this reason, the present work has the aim of describing the origin and insertion of the nerves that constitute the brachial plexus in roadside hawks (*Rupornis magnirostris*).

MATERIALS AND METHODS

Five female roadside hawk carcasses (*Rupornis magnirostris*) were used to the study. They were donated frozen to the Animal Anatomy Laboratory of the São Judas University Center, UNIMONTE campus, by *CEPTAS* (Center for Research and Screening of Wild Animals).

The roadside hawks were fixed with 10% formaldehyde solution and then packaged in the same solution for a minimum period of 48 hours. Dissection was performed by incision, folding the skin and subcutaneous tissue of the axillary region, followed by removing the sternum, along with the pectoral and supracoracoid muscles through the section of the ribs, coracoid bone and clavicle, exposing and individualizing the nerves composing the brachial plexus in both antimeres.

The nerve roots were individualized near the vertebral column in order to observe which ventral branches of the cervical and thoracic spinal nerves contribute to forming the brachial plexus. Thus, the cervical vertebrae and the first pair of ribs were identified. After identification of these levels, nerve dissection was then performed. The brachial plexus arrangement was documented and the nomenclature used for the anatomical description is according to the Avian Anatomical Nomenclature (Baumel 1993).

RESULTS

The brachial plexus of the roadside hawk (*Rupornis magnirostris*) is formed by the union of the spinal nerve ventral branches located between the ninth cervical vertebra and the third thoracic vertebra (C9-C10-T1-T2-T3). The ventral branches from origin (roots) form the short nerve trunks (four short trunks) that join, promoting an exchange of fibers and forming a big caliber trunk outside the coelomic cavity (Figure 1a) which divides into nerve cords extended to specific muscle groups (Figure 1b-c).

The first nerve stem originated from the intervertebral space between C9 and C10. This short nervous trunk emitted an isolated nervous filament, which did not join with the other short trunks, following directly to the rhomboid, sternocoracoid and supracoracoid muscles

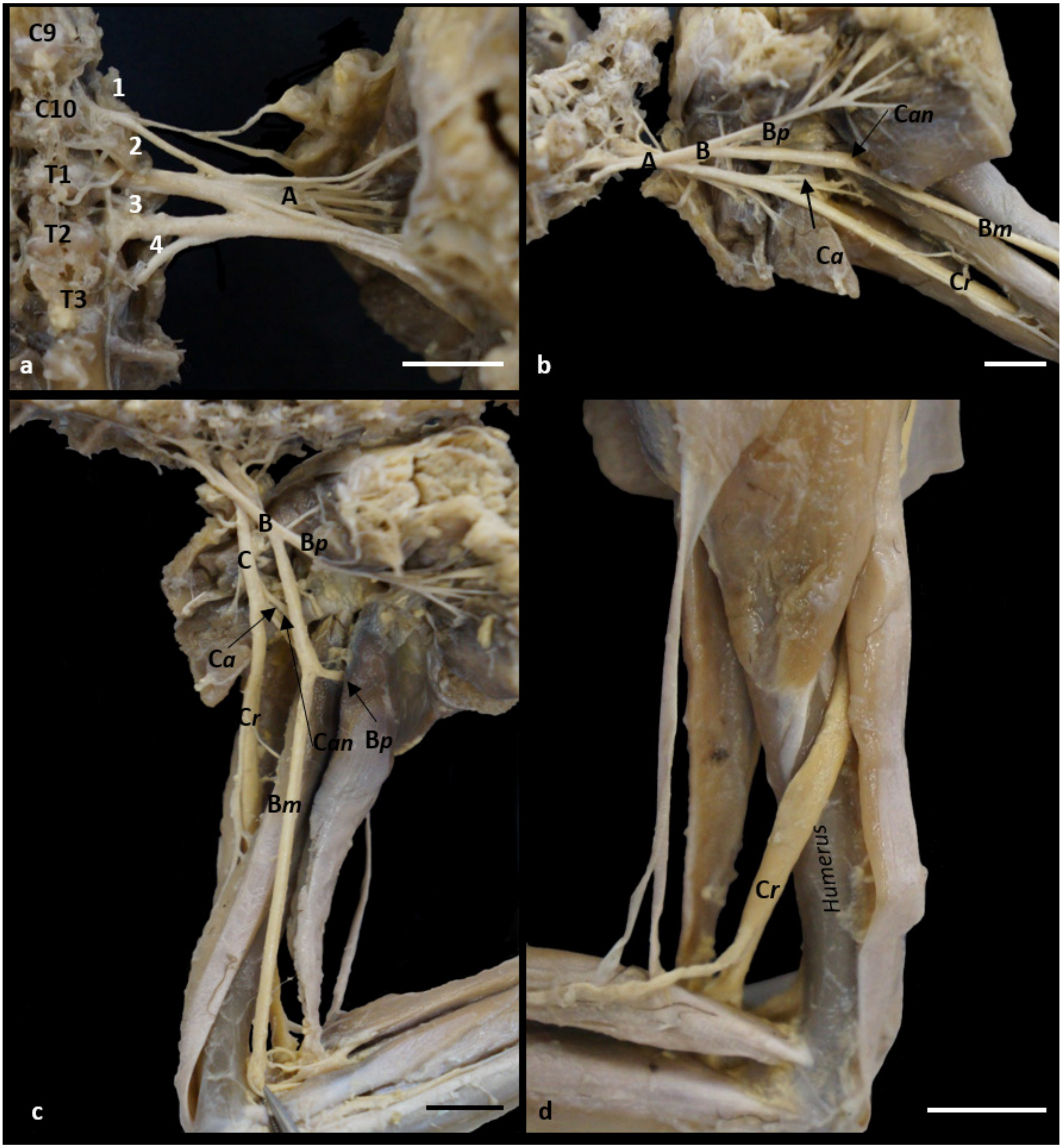

Figure 1. Photomacrographs of the brachial plexus of the roadside hawk (*Rupornis magnirostris*). a-b: ventral view; c: medial view; d: side view. Scale bar: 1.0cm. Legend: C9- Ninth cervical vertebra, C10- tenth cervical vertebra, T1- first thoracic vertebra, T2- second thoracic vertebra, T3- third thoracic vertebra, 1- origin of first short nerve trunk, 2- origin of the second short nerve trunk, 3- origin of the third short nerve trunk, 4- origin of the fourth short nerve trunk, A- short trunk; B- ventral branch, Bm- median-ulnal nerve, Bp- bicipital nerve, C- dorsal branch, Ca- axillar nerve, C*an*- anconal nerve, Cr - radial nerve.

(Figure 1a). The first (between C9-C10) and the fourth (T2-T3) short nerve trunks presented a more tenuous appearance when compared to the second (between C10-T1) and the third (T1-T2) short trunks, which were thicker (Figure 1a).

The four short trunks formed together into a single, fairly thick trunk, dividing into two nervous cords after passing through the wall of the coelomic cavity. However, a nervous filament originating from the fourth short trunk does not join, advancing directly to the arm and inserting into the humerus triceps and scapulo-triceps muscles.

The ventral and dorsal cords followed directly to the arm. The pectoral nerve arose from the initial portion of the ventral cord at its cranial border, which followed horizontally and emitted its nerve branches to the pectoral muscle. Afterwards, the bicipital nerve was verified in the more cranial portion of the arm, innervating the biceps brachial muscle. The ventral cord then continued to the medial region of the arm as a median-ulnar nerve, which continued its course to the cubital fossa where it divided into median nerve and ulnar nerve. The median-ulnar nerve is exposed in the medial region of the arm. The branches of the ventral cord supply the ventral (flexor) compartment muscles of the limb (Figure 1b-c).

The axillary nerve emerged in the initial portion of the dorsal cord, which went to the dorsal portion of the shoulder. Afterwards, the dorsal cord continued to the arm as a radial nerve. The anconeal nerve appeared from the caudal surface of the radial nerve, very close to the origin of the axillary nerve, innervating the humerus triceps muscle (Figure 1b-c). The radial nerve contoured the humerus to the lateral region of the arm in its proximal third, being visualized superficially in the middle and distal third of the humerus without any muscular protection (Figure 1d). The branches of the dorsal cord supply the dorsal (extensor) compartment muscles of the limb and the overlying skin.

DISCUSSION

The study of the brachial plexus in birds, especially in wild birds, is not only important for morphological knowledge, but also for the early diagnosis of diseases that affect the plexus and compromise their flight. These disorders can include acute injuries as a result of trauma, usually the main cause of the radial nerve paralysis (midair collisions, automobile accidents, gunshots, bite wounds, lacerations and iatrogenic damage during surgical procedures and injection of therapeutic agents) (Antolitou et al. 2012, Shell et al. 1993). Moreover, even the radial nerve rupture is possible, due to its proximity to the diaphysis of the bone and the small amount of musculature present in the region (Bolson et al. 2005). Besides, an avulsion or tearing of these nerves root can also occur (Stephen & Smith 1993). In this case, the damage can be permanent, including lack of pain perception, muscle atrophy and paralysis with loss of reflexes (Ritchie et al. 1994).

Furthermore, the morphological knowledge is essential for surgical approach, such as fractures corrections (Bolson & Schossler 2008) or amputation (which is required when infections, neoplasias, severe radial nerve paralysis or chronic malunion fractures compromise the systemic health of the patient) (Latney et al. 2018). In addition, this knowledge is extremely useful for local and regional anesthetic procedures (Vilani et al. 2006, Soresini et al. 2013, Balthazar 2016, Nascimento et al. 2019, Credie et al. 2019). The lack of information regarding the distribution and location of the brachial plexus nerves in these animals may be a limiting factor for such procedures.

The spinal nerves that constitute the brachial plexus of birds may vary among species since there are variations between the number of vertebrae in each region (Nickel et al. 1977). Information about the origin and insertion of the nerves that constitute the brachial plexus of the roadside hawk (*Rupornis magnirostris*) is scarce, so the present research conducted a comparison with other bird species.

Roadside hawks presented four nerve origins (or roots) located between the vertebrae C9-C10, C10-T1, T1-T2 and T2-T3. Although the nervous origin varies among birds due to the different number of vertebrae in each region, hens presented similarity to the roadside hawks, having the origin of their plexus between the last two cervical segments and the first three thoracic segments (Nickel et al. 1977). In the present study, it was observed that in the vulture (*Coragyps atratus foetens)* (Moreira et al. 2009), the burrowing owl (*Athene cunicularia*), the american barn owl (*Tyto furcata*) (Silva 2016) and blue fronted amazon parrots (*Amazona aestiva*) (Silva et al. 2015) also presented four nervous origins at the cervicothoracic junction, but between different vertebral levels. Differently, Franceschi et al. (2009) reported only three nervous origins in pigeons (*Columba livia*), as well as Nickel et al. (1977) in ducks (*Anas platyrhynchos*) and geese *(Anser anser*), Moreira et al. (2005) in turkeys (*Meleagris gallopavo*), and Achôa Filho et al. (2014) in the blue-and-yellow macaw (*Ara ararauna*).

As previously verified, there is no standardization defined in the brachial plexus of birds (Nickel et al. 1977). This variability in the number of origins is probably related to the size and quantity of cervical and thoracic vertebrae, a fact that can modify the number of intervertebral foramina, directly influencing the point of origin of the nerve trunks.

The short nerve trunks are formed after the exit of the nerves through the intervertebral foramina, in which there is an interchange of fibers (Baumel 1986). These trunks cross a triangular hiatus when emerging from the coelomic cavity, cranially occupying this space (Soresini et al. 2013). The roadside hawks presented four nervous origins that constituted four short trunks, similar to the blue fronted amazon parrots (Silva et al. 2015) and the burrowing owl (Silva 2016). The vulture also presents four nervous origins, but with the formation of three short trunks (Moreira et al. 2009). Turkeys (Moreira et al. 2005) and blue-and-yellow macaws (Achôa Filho et al. 2014) present three origins with the formation of three short trunks. In the American barn owl, Silva (2016) reported the presence of five short trunks.

In the same way that it was observed in the dissected roadside hawks, the specific literature consulted was unanimous in reporting the union of the brachial plexus forming nerve trunks in a common trunk, with dorsal and ventral cords separating and whose branches respectively supply the nerves of the extensor compartments, the wing flexor, and overlying skin. The nerves coming from the dorsal cord observed in the hawks were the axillary nerve, the anconeal nerve and the radial nerve. These nerves are responsible for innervating the wing extensor musculature and are also found in the turkey (Moreira et al. 2005), in the burrowing and American barn owls (Silva 2016), in the vulture (Moreira et al. 2009), and in the blue fronted amazon parrot (Silva et al. 2015). There is no description of the anconal nerve in the pigeon (Franceschi et al. 2009). The nerves that emerge from the ventral cord are the pectoral nerve, bicipital nerve, median-ulnar nerve, median nerve and ulnar nerve, which innervate the wing flexor muscles, and are the same described in the mentioned species.

CONCLUSION

An important detail observed regarding the distribution of the brachial plexus nerves was the location of the radial and median-ulnar nerves; the radial nerve is superficially found at the humerus without muscular protection when transpassing from the medial to lateral aspect, which suggests fragility in the peripheral system, as well as the median-ulnar nerve in the medial view, with these areas being susceptible to traumas.

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DEREK L. MACHADO[1]
https://orcid.org/0000-0003-0096-8786

THIAGO LEZARDO[1]
https://orcid.org/0000-0001-9220-573X

JULIANA P. GUIMARÃES[1]
https://orcid.org/0000-0002-6511-8718

NAIANNE K. CLEBIS[2]
https://orcid.org/0000-0002-1749-7565

KARINA M. GAGLIARDO[1]
https://orcid.org/0000-0001-6730-3661

[1]Centro Universitário São Judas, *campus* UNIMONTE, Faculdade de Medicina Veterinária, Rua Comendador Martins, 52, Vila Mathias, 11015-530 Santos, SP, Brazil

[2]Universidade Federal do Rio Grande do Norte/ UFRN, Departamento de Ciências morfológicas, BR 101, Lagoa Nova, 59072-970 Natal, RN, Brazil

Correspondence to: **Juliana Placido Guimarães**
E-mail: juvetpg@yahoo.com.br

Author contributions

KMG, JPG and NKC conceived and planned the experiments. DLM and TL carried out the experiments. KMG, DLM and TL contributed to the interpretation of the results and took the lead in scientific writing the manuscript. KMG guided the work and supervised the steps previously described. All authors provided critical feedback and helped shape the research, analysis and manuscript.