Radiographic, tomography and three-dimensional description of the clinical anatomy of the long bones of Rupornis Magnirostris

Descrição radiográfica, tomográfica e tridimensional da anatomia clínica dos ossos longos de Rupornis Magnirostris

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ABSTRACT

Birds of prey play an important role in the ecological balance of several biomes, but their proximity to urban areas often causes harm to the animal. The investigation of clinical surgical approaches requires a precise understanding of the anatomical system, especially when applied to imaging exams of wild animals. In this article we present the clinical anatomy of the long bones of *Rupornis magnirostris*, roadside hawk, focusing on its express form in the imaging tests adopted. Cadavers were submitted to digital radiography and computed tomography, providing models of both two-dimensional images and three-dimensional images of long bones through the segmentation of tomographic images, both 2D and 3D data were contrasted by anatomical dissection. In this article we obtain: (1) A summary of the nomenclature used in the literature of the long bones of the birds perceived in the imaging examinations. The approach presented here provides considerable advantages for the interpretation and communication of anatomical information and its visualization; (2) the 3D model produced from the segmentation process as an interactive model in the form of an embedded 3D image, which can be viewed at any angle and size, allowing the structure to be evidenced as necessary to provide an understanding of the normal anatomy of long bones of this species.

Keywords: bird of prey, 3D anatomy, 3D medical.

RESUMO

As aves de rapina desempenham um papel importante no equilíbrio ecológico de diversos biomas, mas sua proximidade com áreas urbanas costuma causar danos ao animal. A investigação de abordagens clínico-cirúrgicas requer um conhecimento preciso do sistema anatômico, principalmente quando aplicado a exames de imagem de animais silvestres. Neste artigo apresentamos a anatomia clínica dos ossos longos de *Rupornis magnirostris*, gavião de beira de estrada, focando sua forma expressa nos exames de imagem adotados. Os cadáveres foram submetidos a radiografia digital e tomografia computadorizada, fornecendo modelos tanto imagens bidimensionais quanto imagens tridimensionais de ossos longos por meio da segmentação de imagens tomográficas, ambos os dados 2D e 3D foram contrastados por dissecação anatômica. Neste artigo obtemos: (1) Um resumo da
nomenclature utilized na literatura dos ossos longos das aves percebidos nos exames de imagem. A abordagem aqui apresentada oferece vantagens consideráveis para a interpretação e comunicação de informações anatômicas e sua visualização; (2) o modelo 3D produzido a partir do processo de segmentação como um modelo interativo na forma de uma imagem 3D incorporada, que pode ser visualizada em qualquer ângulo e tamanho, permitindo que a estrutura seja evidenciada como necessária para fornecer uma compreensão da anatomia normal de ossos longos desta espécie.

Palavras-chave: aves de rapina, anatomia 3D, medicina 3D.

1 INTRODUCTION

Central and South America concentrate the highest diversity of predator species (SICK, 1997) and approximately 23% of all falconiform species occur in Brazil (BIRDLIFE INTERNATIONAL, 2018). Among the predators, the roadside hawk, *Rupornis magnirostris*, is a species of extreme ecological importance, participating in the control of the populations of arthropods, small lizards, snakes, rodents, birds and bats, thus maintaining the balance of fauna (SANTOS & ROSADO, 2009). However, the intensification of anthropic action increases the pressure on the various biomes, leading to habitat loss and increasing the contact of wild animals with urbanized areas (ICMBio, 2015).

The ability to fly provides evolutionary advantages of being able to access inhospitable areas, food sources, perform migration, as well as the ability to perform aerial maneuvers ensuring rapid hunting and escape ability. This is a crucial point in the conservation of avian species, especially for predators that depend on active hunting. The key to bird flight is intrinsically linked to the presence of air sacs and their diverticula that enter the long bones through the pneumatic foramen such as humerus and femur, being more developed in birds that fly a lot (SANTOS & ROSADO, 2009; MAIER & KONIG, 2016).

Despite the considerable variation of birds of prey species, the basic skeleton design is consistent across the Avian class. Like mammals, many bones of the avian skeleton develop from a cartilaginous model that is gradually replaced by bone. In long bones, this process begins by converting the connective tissue around the cartilage into a
thin bone collar through a process known as perichondral ossification. Pneumatization refers to the development of air-filled cavities in the bone that provide lightness to the avian’s body and functions as one of the factors influencing flight ability. Specific knowledge of normal birds imaging anatomy is required to interpret radiographs correctly for each species. As the pneumatized bones are a prominent anatomical area, they can easily be misinterpreted, especially in wild animals (MAIER & KONIG, 2016).

Avian orthopedic conditions, in particularly fractures, occur very frequently in long bones, directly impeding the ability to fly. For this very reason, especially in wild birds, a complete return to normal functions is always objectified in medical and surgical clinics. It is necessary to have an accurate clinical understanding of the situation so the best therapeutic choice can be made. In the clinical-surgical approaches, imaging exams are fundamental in the assessment of injuries, whether primary or secondary to trauma in birds, providing a precise diagnosis necessary to implement appropriate therapy for these animals, although information about their biology is rare, despite of being a very common species in the Brazilian metropolitan regions (BURGDORF-MOISUK et al. 2017; CARRASCO et al. 2017; FIRMINO, M. O. et al.; Sampaio, B. F. B. 2014; D. E. SCOTT, 2016; VELADIANO, I. A. et al. 2016).

Radiology over the years has become a valuable tool for routine procedures in birds, guiding professionals to close diagnoses for various avian pathologies (PINTO, et al. 2014). Computed tomography contributes more clearly to the visualization of fractures and bones alterations, without the need for special positions for better image capture. The use of this technique should be considered in suspicion of lesions not identified radiographically (MAIER & KONIG, 2016). CT combined with three-dimensional visualization techniques, provides a powerful diagnostic tool through the richness of morphological details. The exam can be applied not only for diagnosis, but also for descriptive and illustrative purposes, especially when associated with computational analysis, expanding the range of possibilities and providing clarity to professionals. The internal structures of the animal body can be difficult to visualize, and classical dissections require the unique combination of a researcher who is patient and endowed with appropriate artistic skills. However, three-dimensional computation and digital
modeling can provide morphological and anatomical information in a minimally invasive and much faster way (LAUTENSCHLAGER, et al. 2014).

Considering the information found in the literature, it is evident that the high frequency of injuries compromises the life and well-being of these birds. In this context, joint research between imaging techniques and anatomical approach is fundamental as a measure for the preservation and understanding of anatomical, taxonomic, evolutionary and ecological aspects (SANTOS & ROSADO, 2009). This article aims to describe the long bones in the radiographic and tomographic image of *Rupornis magnirostris*, establishing correlation to the anatomical findings and their 3D projections.

2 METHODS

For this study 9 adult roadside hawk (*Rupornis magnirostris*) were used, from the Batalhão de Policia Militar de Proteção Ambiental de Várzea Grande, Mato Grosso (BPMPA-VG), belonging to the Secretaria de Estado de Meio Ambiente de Mato Grosso (SEMA-MT) to perform imaging exams and three of these were used for anatomical compare. All procedures adopted are authorized by the Ethics Committee of the Universidade Federal de Mato Grosso.

The radiographs were obtained by the RAICOM SH300D® device following the protocol already described by Pinto (2014), being the exposure from 0.017 seconds (1/60) to 300 milliamperes (mA) and 60 kilovolts (kV). The radiographic incidences were ventrodorsal and laterolateral, minimizing the overlap of the 16856oné structures. The images were submitted to the VitaFlex® radiographic digitizer and the digital images were processed and analyzed using Carestream® software.

The helical CT was performed by means of a scanning of 2 rows of detectors with transversal capture, using the SOMATOM Spirit Siemens®. The image was taken craniocaudal from the whole extension of the animal’s body, which was placed on the ventrodorsal decubitus on a padding with stabilized wings, legs and head. The following parameters were applied: child-long 16856oné protocol, FOV 512 mm, 1.0 pitch, 90 kV and 10 mA(s). All images were first analyzed in the Syngo CT 2010C® equipment in multiplanar form and then in 3D reconstruction. Subsequently the data were transformed
into Digital Imaging and Communications in Medicine (DICOM) format and exported to a CD-R.

The data obtained by the CT were visualized and manipulated in the Workstation of the Surgical Center with the use of free software InVesalius 3.1®, allowing to show the anatomical structures in the multiplanar cuts and to emulate its 3D projection using 16857onés1685716857te filters. For this, a mesh of polygons was created from the Halsted density threshold, providing rendering of the desired study 16857oné, obtaining 2D images, manipulating 3D projection and saving it in .stl (stereolithography) format. In the sequence, the file was opened in MeshMixer® free software to finish and smooth the model, correcting possible image capture artifacts, providing a more realistic, dynamic and interactive anatomical piece.

After imaging exams, the corpses were wrapped in bandage fabric and submerged in 10% formalaldehyde solution in a container with a lid to ensure fixation of the pieces. Manual dissection was performed on three specimens in the 16857onés of interest, releasing the musculature through the fascia and removing the tendons with a n15 scalpel, exposing the humerus, radius, ulna, femur, tibiotarsus and fibula on both sides without disarticulation at first for analysis and photographic capture. After the bones were isolated and sanitized in running water and later with hydrogen peroxide in order to finalize the anatomical pieces, making possible the identification of the structures in situ and comparing to the digital images.

3 RESULTS AND DISCUSSION

Anatomical and radiological images of *R. magnirostris* corpses using x-ray, CT and dissection, respectively, are made to highlight the differences and similarities between these two diagnostic modalities and their findings in situ. The anatomical pieces were isolated and used as parameters (Figure 1) for analysis of the images exams. As shown in Figure 2 the x-ray allows visualization of the bones at a two-dimensional level of the bone structures, with high detail resolution. CT is particularly a useful tool for dense structures like bones and natural radiodensity contrasts, such as the difference between hard tissue and air, allowing such bones and air sacs to be clearly seen in both
sectional and 3D rendering images (Figure 3). Both radiography and CT allow visualization of the long bones and their anatomical structures for this species, aiding in the more precise clinical diagnosis.


Fonte: Arquivo Pessoal.

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Figure 3 - Computer Tomography images. 3.A - Humerus proximal extremity. 1-Humerus head, 2- Ventral tubercle, 3-Pneumatic foramen, 32-Air sac.

Fonte: Arquivo Pessoal.
Figure 4 - 3.B - Humerus Body. 4-Humerus body, 6-Ventral epicondyle, 7-Dorsal epicondyle, 32-Air sac.

Fonte: Arquivo Pessoal.
Figure 5 - 3.C - Humerus distal extremity. 4-Humerus body, 5-Ventral condyle, 6-Ventral epicondyle, 7-Dorsal epicondyle, 32-Air sac.

Fonte: Arquivo Pessoal.
Figure 6 - 3.D - Ulna and Radius proximal extremity, 8-Olecranus, 9-Body of ulna, 10-Distal extremity of ulna, 11-Proximal extremity of radio, 12-Radio body, 13-Radio distal extremity.

Fonte: Arquivo Pessoal.
Figure 7 - 3.E - Ulna and radius distal extremity. 9-Body of ulna, 10-Distal extremity of ulna, 12-Radio body, 13-Radio distal extremity.

Fonte: Arquivo Pessoal.
Figure 8 - 3.F - Femur proximal extremity. 14-Trochanter, 15-Femur head, 16-Femur neck, 17-Femoral Body, 32-Air sac.

Fonte: Arquivo Pessoal.
Figure 9 - 3.G - Femur distal extremity. 14-Trochanter, 17-Femoral Body, 18-Lateral condyle, 19-Medial condyle, 21-Patellar crest, 22-Cranial cnemial crest, 32-Air sac.

Fonte: Arquivo Pessoal.
Figure 10 - 3.H - Tibiotarsus and Fibula proximal extremity. 21-Patellar crest, 22-Cranial cnemial crest, 23-Body of tibiotarsus, 29-Head of fibula, 30-Body of fibula, 32-Air sac.

Fonte: Arquivo Pessoal.
The use of CT enabled the rendering of both the long bones and the air sacs, providing 2D images and interactive files in 3D format (Figure 4). The sequential slices of the CT scans generate images with less detail of structures for this species with this equipment when compared to a larger animal as a dog, but guarantees the understanding of the bone structures as their particularities, bone accidents, areas of cortex, marrow area, air sacs and their possible changes.
The anatomical structures evidenced in this study were: Humeral head, Ventral tubercle, Pneumatic foramen, Humerus body, Ventral condyle, Ventral epicondyle, Dorsal epicondyle, Olecranus, Body of ulna, Distal extremity of ulna, Radius proximal extremity, Radius body, Radius distal extremity, Trochanter, Femur head, Femur neck, Femoral Body, Lateral condyle, Medial condyle, Intercondylargroove, Patellar crest, Cranial cnemial crest, Body of tibiotarsus, Medial condyle, Lateral condyle, Intercondylar Incisure, Extensor groove, Supratendinal bridge, Head of fibula, Body of fibula, Fibula spine, Air Sac.

Digital radiography remains a basic and a fundamental tool in orthopedic diagnosis in bird clinical routine. The identification of structures and bone changes can be detected by radiography in the laterolateral and ventrodorsal planes, with minimal overlap. In general, the diagnostic procedures should consist of conventional radiographs made in two planes, followed by computed tomography, if the results of digital radiography are unsatisfactory to identify the structures or pathology investigated (GUMPENBERGER, 2011).
The advantage of computed tomography is based on the ability to create multiple x-rays without overlapping of structures sequentially, bone extensions and air sacs are clearly visible at different scans and without the need for special positions. Axial slices are advantageous when compared to digital radiographs, since they allow the visualization of multiple structures, as well as allowing the precise understanding of the limitations of anatomical structures (VELADIANO, et al. 2016), as a cortical, medullary region and air sacs. Another CT tool is the analysis of the dorsoventral and longitudinal slices rendered from the craniocaudal scan, which can be compared directly with lateral radiographs, which are commonly performed before the tomography, but because it is a reconstruction, there is a decrease in resolution and detailing when compared to axial projection.

Research shows that there are benefits in teaching and learning anatomy with health professionals and the like using virtual reality. In modern education the use of virtual reality with 3D data obtained through the CT is beneficial to accelerating and improving the learning curve. However, the most commonly applied option remains the use of cadaver dissection. There may, however, be an alternative that replaces the need for cadaver dissection, such as CT data capture, 3D visualizations and computer generated models, that is, Post Mortem 2D and/or 3D images, videos and models printed by rapid prototyping (RUTTY, J. et al. 2019).

3D rendering from tomographic imaging is definitely a milestone for modern anatomical science. Providing singular positive points, such as the feasibility of studying and revising anatomical parts in a biosecure way, repeatedly without the need to be in an anatomy laboratory due to its portability. A key point of note for this technique is that it can digitally manipulate a structure in its 360º, zoom in/out and highlight areas of interest without necessarily making the part unfeasible for other functions due to its digital format. The models also stand out in the storage question, since they are compatible with diverse formats and places like; Computers, Clouds, External HD, SSD, SD Card, Pen Drive, CD-R, etc. (LAUTENSCHLAGER, et al. 2014).

However, the CT data detailed resolution is directly linked to the number of sensors, the model of the tomograph and the adopted protocol, being preferred to use
thinner slices for greater capture of bone details in a smaller capture area. The tomographic equipment and its added value are the most problematic for the acquisition of reliable 3D projections quickly and non-invasively, since both softwares required for analysis is free and does not require supercomputers to process the data (PINTO, et al. 2014).

4 CONCLUSIONS

We affirm that it is possible to identify the long bones and their particularities of the anterior and posterior limbs of *Rupornes magnirostris* through the radiography and CT, guaranteeing clarity and easy understanding of the basic anatomical components in the imaging examinations. Expressing tomographic and radiological images compared to anatomical images of long bones using an informative language for veterinary students and specialists. The association of macroscopic, radiological and tomographic images facilitates the identification of anatomical structures with greater precision in the examinations. In addition, it serves as a parameter for the writing of image reports and allows the surgical planning of the species in question. Computed tomography enabled, in addition to the clinical images, to render three-dimensional anatomical models that further facilitate the anatomical understanding in a dynamic and interactive way. Precise studies on the anatomical image of raptors are crucial for better understanding and radiological interpretation, guiding professionals to decide on better planning to be adopted in veterinary routine.
REFERENCES


