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Ring-tailed Lemur (*Lemur catta*) Anatomy

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Abstract

The ring-tailed lemur (*Lemur catta*) is primarily distributed in south and south-western Madagascar. It is classified as an endangered species by the International Union for Conservation of Nature and Natural Resources. The ring-tailed lemur is a species commonly kept in zoological gardens. Diseases involving various body systems such as musculoskeletal, digestive, circulatory, respiratory and urogenital systems have been reported in the ring-tailed lemur, which threatens their survival. This review describes the normal anatomy of the ring-tailed lemur as a reference for clinical use and species identification. Variations exist in the normal anatomy of different animal species. Knowledge of the normal anatomy of individual species is important for accurate diagnosis and treatment of diseases.

Keywords: Anatomy; *Lemur catta*; Osteology; Radiography; Ring-tailed lemur; Ultrasound.

1. Introduction

The ring-tailed lemur (*Lemur catta*) (Figure 1) is classified as an endangered species by the International Union for Conservation of Nature and Natural Resources [1]. It belongs to order; Primata, suborder; Strepsirrhini, family; Lemuridae, and genus; *Lemur* [2]. Most strepsirrhines resemble more primitive animals by retaining characteristics such as pointed muzzle, rhinarium, prominent scent glands, tapetum lucidum, small brain case, open eye sockets, bicornuate uterus and epitheliochorial placenta [3, 4]. Similar to other primates, strepsirrhines have high degree of orbital frontality, the hind limbs are longer than the forelimbs and they have flat nails in most of the digits [4].

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The head and body length of the ring-tailed lemur ranges from 38.5 cm to 45.5 cm (mean; 42.3 cm), whereas the mean length of the cranium is 8.4 cm (range; 7.8 cm to 8.8 cm) [5]. The tail measures 56 cm to 62.4 cm (mean; 59.5 cm) [5]. In the wild, ring-tailed lemurs weigh 2.2 kg [6, 7]. Captive ring-tailed lemurs weigh slightly more than their wild counterpart, in which the average weight of females and males has been reported to be 2.678 kg and 2.705 kg, respectively [7, 8]. Further, the average lifespan of males and females in captivity is 20 years and 18 years, respectively [7]. In the wild, it is rare for females to live past 16 years, whereas males have been recorded living to at least 15 years of age [7].



Figure 1: A photograph of adult ring-tailed lemurs (*Lemur catta*)

The ring-tailed lemur is primarily distributed in south and south-western Madagascar [9]. It is a quadruped arboreal animal, which spends up to one-third of its time on the ground [4]. The habitat of the ring-tailed lemur consists of mixed forests, continuous canopy forests and brush and scrub forests [9]. The brush and scrub forests are dominated by *Maerua filiformis*, *Guisivianthe papionaea*, *Azima tetracantha* and *Salvadora augustifolia*, whereas the continuous canopy forests are dominated by *Celtis gonipophylla* and *Tamarindus indica* [9]. Higher density of ring-tailed lemurs occurs in areas with higher density of tamarind trees [5]. The latter, is a favorite for both shade and food [5]. Trees provide sites for food and sleeping [5].

Ring-tailed lemurs are opportunistic omnivores eating primarily on fruits [7]. They also extensively feed on leaves [5, 7]. In the wild, mature leaves and fruits of the tamarind tree are heavily utilized [5, 7]. Additionally, they also prefer fruits of *Rinorea greveana* and *Pithecelobium dulce* [7]. Apart from fruits and leaves, they also have been observed feeding on insect cocoons, spider webs, decayed wood, earth, small vertebrates and

arthropods such as grasshoppers, spiders, caterpillars, and cicadas [7]. In captivity, they are fed with starch vegetables, fruits, leafy greens, vegetables and commercially prepared nutritional complete biscuits [7, 10].

This review describes the normal anatomy of the ring-tailed lemur as a reference for clinical use and species identification.

2. Anatomy

2.1. Integumentary system

The body of the ring-tailed lemur is covered with a grey to grey-brown pelage, which is slightly darker around the neck and head with the exception of the face and the ventral side [5]. The face, throat and underside are lightly haired with a paler, off-white colour [5]. The tail is sharp ringed with 12 or 13 white rings alternating with 13 or 14 black rings and presents with a black tip [5]. The skin is black or dark grey in colour and the entire epidermis is heavily pigmented, which is most evident in the regions lacking hair such as the scrotum, palms, soles, eyelids and lips [5]. Bates [11] documented the presences of multiple scent glands (genital, antebrachial and brachial) in male ring-tailed lemurs and only one scent gland in female ring-tailed lemurs located in the genital area. According to Wilson and Hanlon [5], the antebrachial scent gland is present in both sexes, whereas the brachial scent gland is barely developed in females. However, the authors in [12] reported the visualisation of the brachial and antebrachial scent glands in only male animals on radiographic examination.

2.2. Musculoskeletal system

The number of cervical, thoracic, lumbar, and sacral vertebrae in a ring-tailed lemur is 7, 12, 7, and 3, respectively, with a total of 19 thoracolumbar vertebrae [13, 14]. However, it is uncommon to find ring-tailed lemurs with 13 thoracic and 6 lumbar vertebrae [15]. Additionally, 20 thoracolumbar vertebrae have been observed in a ring-tailed lemur with 13 and 7 thoracic and lumbar vertebrae, respectively [15]. The number of caudal (coccygeal) vertebrae ranges from 20 to 24 [16]. The spine is fairly horizontally aligned and the length of the vertebral bodies of the thoracolumbar spine increases from cranial to caudal up to the fifth lumbar vertebra [13, 14]. The spinous processes of the thoracic spine are almost of the same height with the thoracic vertebra 10 (T10) being mainly an anticlinal vertebra [13]. The spinous processes of the lumbar vertebrae are wide craniocaudally and directed cranially [14]. The interarcuate spaces between caudal thoracic to cranial coccygeal vertebrae are wide and most likely allow flexibility of the spine as an adaptation to jumping [15].

There are generally 12 pairs of ribs, which correspond to the number of thoracic vertebrae. The last pair of ribs is floating [13]. The sternum is slender and fairly straight consisting of manubrium sterni, xiphoid process and five or four sternbrae [13]. Fusion of the last two or three sternbrae may also be observed in ring-tailed lemurs [13]. Ring-tailed lemurs have a very narrow thoracic inlet with abdominal dominance [13, 15]. In heavy ring-tailed lemurs accumulation of abdominal fat is usually seen in the retroperitoneal space and cranioventral abdomen, which provide sufficient contrast for visualisation of abdominal organs of clinical importance [14]. Additionally, hypaxial muscles are conspicuous [14].

The scapula of the ring-tailed lemur is elongated proximodistally and narrow craniocaudally so as to allow rapid

movement of the thoracic limb and at the same time to provide an adequate area for the insertion of the scapulovertebral muscles probably as an adaptation to both terrestrial and arboreal lifestyles [12]. The clavicle and the hamate process are well developed. The major tubercle of the humerus does not extend higher than the humeral head [12]. The prominent, ovoid area for the insertion of the infraspinatus muscle is at the same level as the head of the humerus and presents as a shallow fossa [12]. The lateral supracondylar crest is well developed. The medial epicondyle of the humerus is larger and well developed than the lateral epicondyle [12]. The head of the radius is elliptically shaped and the prominent radial tuberosity is relatively further distally located [12]. The cranio-laterally located radial notch is fairly rounded with a single articular facet that projects from the surface of the ulna [12]. The ulnar head is well developed. The ulnar articular circumference projects cranially from the surface of the body [12]. The five metacarpal (MC) bones are widely spread and the first MC bone diverges further medial from the rest of the MC bones [12]. The above features indicate the presence of strong flexor muscles of the thoracic limb and flexibility of thoracic limb joints [12]. There are nine carpal bones arranged in three rows. The proximal row consists of the radial, intermediate, ulnar and the accessory carpal bones. The middle row contains the central carpal bone. The distal row includes the first, second, third and fourth carpal bones [12]. The supracondylar foramen is present [12].

The middle third of the cranial half of the ilial wing of the ring-tailed lemur is marked thinner than the dorsal and ventral thirds, as a result of the presence of the stretching ligament (*Ligamentum interspinosum*), which increases the surface of the ilial wing without increasing the weight of the bone probably as an adaptation for jumping [17]. The caudal ventral iliac spine is well developed in this species and is associated with the locomotor adaptation for jumping [17]. The caudal ventral iliac spine provides origin for the m. rectus femoris, which is an extensor of the stifle joint during jumping [18]. The strength of this muscle is supported by the presence of the prominent tuberosity on the cranial surface of the patella [17], which provides its insertion [18]. The prominent tuberosity on the cranial surface of the patella in this species further increases the moment arm of the m. quadriceps femoris in extension of the stifle joint [19]. The femoral trochlea, which is deep and narrow, is surrounded by prominent medial and lateral ridges with the lateral ridge being thicker and more elevated than its medial counterpart [17]. These features prevent lateral luxation of the patella as a result of rapid and powerful extension of the stifle [19, 20]. The major trochanter extends proximal above the head of the femur. The caudolaterally and caudomedially located third and minor trochanters, respectively, are well developed. The latter, is not connected to the major trochanter by the inter-trochanteric crest [17]. The extensor fossa is absent [17]. The cochlea of the tibia presents as an almost flat surface without an intermediate ridge and trochlea of the talus is shallow, which facilitate supination of the foot, which is important in quadrupedal arboreal animals [17].

There are seven tarsal bones arranged in three rows. The proximal row consists of the calcaneus and talus tarsal bones. The middle row contains the central tarsal bone. The distal row includes the first, second, third and fourth tarsal bones [17]. The central tarsal bone is elongated proximodistally as an adaptation for jumping [17]. The elongated central tarsal bone increases the tarsal leverage for jumping [18]. There are five metacarpal (MC) and metatarsal (MT) bones, which are widely spread [12, 17] and provide a large space for the effectiveness of the muscles, which are responsible for small movements of the digits [21]. The first MC and MT bones diverge further medial from the rest of the MC and MT bones, respectively, which is associated with the manus and foot being efficient grasping tools during feeding and locomotion [12, 17]. An inter-phalangeal ossicle is always seen

in the first digit of the manus and foot [12, 17]. Furthermore, ossicles may also be seen in the lateral meniscus and in the infrapatellar fat pad [17].

2.3. Respiratory system

The epiglottis is large and the thyroid cartilage is not perforated in mid-line [16]. The thoracic inlet measures 1.99 ± 0.07 cm in average on the right lateral (RL) radiographic view [13]. The cartilaginous rings of the trachea are complete dorsally [15, 16, 22] with a circular lumen [22]. The thoracic part of the trachea is very long [22]. On thoracic radiographs the trachea is seen with mineralised cartilage rings and its mean diameter measures 0.7 ± 0.04 cm at the level of the thoracic inlet on the RL view [13]. The trachea is seen either parallel or deviates dorsally to the spine on the RL view of the thorax, whereas on the dorsoventral (DV) view of the thorax it runs slightly to the right of the spine [13]. The mean position of the carina with respect to thoracic vertebra is 6.7 ± 0.7 and 6.5 ± 0.7 on the RL and DV views of the thorax, respectively [13].

The principal bronchi are relatively short with the left being longer than its right counterpart [22]. The mean angle between the mainstem bronchi measures $82.6 \pm 8.3^\circ$ on the DV view of the thorax [13]. Each principal bronchus splits into two primary branches; the cranial and caudal branches [22]. The cranial branch of the right principal bronchus is confined to the cranial lobe of the right lung, whereas the cranial branch of the left principal bronchus is confined to the cranial lobe of the left lung [22]. The caudal branch of the left principal bronchus is confined to the caudal lobe of the left lung [22]. The caudal branch of the right principal bronchus splits further into two secondary branches, which are confined to the middle, caudal and accessory lobes of the right lung [22].

The left lung consists of two lobes; the cranial and caudal lobes [15, 22]. The cranial lobe is larger than the caudal lobe and it is incompletely subdivided into cranial and caudal parts by a short fissure [15, 22]. The right lung comprises of four lobes; the cranial, middle, caudal and accessory lobes [15, 22]. The cranial and middle lobes of the right lung are irregular in outline [22]. The caudal lobe is triangular in shape [13, 15, 22].

2.4. Circulatory system

The heart is generally cone shaped with a rounded apex and broadened base [22]. On thoracic radiographs the cardiac silhouette is aligned almost parallel to the rib and appears ovoid in shape [13]. The size of the cardiac silhouette has been reported to be less than three intercostal spaces on RL thoracic radiographs [13]. Further, with respect to vertebral heart score the size of the cardiac silhouette has been documented to be 8.92 ± 0.47 and 9.42 ± 0.52 on RL and DV thoracic radiographs, respectively [13]. Pericardial fat may be seen in heavy animals on thoracic radiographs [13].

The spleen is an elongated strap-like structure resembling that of lower mammals [16]. On the ventrodorsal (VD) abdominal radiographs, the spleen is frequently located lateral to the left kidney adjacent to the left body wall and appears either triangular or fusiform [14]. The thickness of the spleen measures 7.56 ± 1.68 mm in average on ultrasonographic examination [14].

2.5. Digestive system

The ring-tailed lemur has 36 teeth, with the following dental formula: I2/2, C1/1, PM3/3 and M3/3 [5]. The upper incisors are small compressed buccolingually, whereas the lower incisors are long, narrow, spatulate and protrude straight forward [5]. The upper canines are large used in slashing attack [5]. The lower canines are slightly larger than the incisors. They are flared laterally with a narrow longitudinal groove on the occlusal surface [5]. The tongue is long and narrow with a pointed apex [16]. The mucosa of the tongue presents with fungiform, vallate and horny conical papillae [16]. The parotid, submandibular and sublingual salivary glands are present, whereas the pharyngeal tonsils are absent [16]. The parotid duct opens in the vestibulum oris [16].

The liver of the ring-tailed lemur consists of four lobes; the left, right, caudate and quadrate lobes [15, 16]. The left lobe is subdivided into the left lateral and left medial lobes [15]. The papillary process of the caudate lobe is very small, whereas the caudate process of the caudate lobe is large and bears a renal impression [15, 16]. The gall bladder is situated in the deep fissure of the quadrate lobe near its right margin [16]. The Y-shaped pancreas is simple not diffuse with the stem of Y directed towards the duodenum [16]. The cranial limb is directed towards the hilum of the spleen, whereas the caudal limb is within the mesentery of the small intestine [16]. The pancreatic duct is single [16].

The stomach is simple and pyriform in shape with the pyloric part lying transversely [16]. On VD abdominal radiographs the pylorus is frequently seen to the right of the spine [14]. Further, the mean angle of the gastric axis has been reported to be $119.77 \pm 7.0^\circ$ with a range of 103° to 130° on RL abdominal radiographs [14]. The ovoid fundus raises little above the level of the cardia [16]. The greater curvature is extensive, whereas the lesser curvature is short [16]. The greater portion of the small intestine possesses a wider diameter especially the duodenum and narrows considerably towards the ileum [22]. The duodenum consists of a longer vertical portion and a shorter transverse portion, which crosses the spine as far as caudally as the fourth lumbar vertebra [16, 22]. The mean external diameter of the small intestine and the ratio compared to the height of the second lumbar vertebral body have been reported to be 0.87 ± 0.21 cm and 1.1 ± 0.26 , respectively, on RL abdominal radiographs [14].

The caecum is very long and large with a conical appendix-like termination [15, 16]. The colon has a characteristic sigmoid arrangement [16]. From the right caudally placed ileo-caecal junction, the ascending colon proceeds oblique cranially and to the left up to the hepatic flexure [15, 16, 22]. From the hepatic flexure to the splenic flexure, the transverse colon pursues a curved course making a U-shaped ansa (15, 16, 22). From the splenic flexure to the anus, the rest of the large intestine takes a straight course caudally [15, 16, 22]. On RL abdominal radiographs, the mean external diameter of the large intestine and the ratio compared to the length and height of the second lumbar vertebral body have been documented to be 1.68 ± 0.49 cm, 1.09 ± 0.3 and 2.18 ± 0.6 , respectively [14].

2.6. Urogenital system

The ring-tailed lemur kidneys are unipyramidal and unlobulated, situated on the dorsal abdominal wall in the

lumbar region [14, 16]. The right kidney is larger than the left kidney and is situated more cranial and dorsal to its left counterpart [14]. The centrally located medulla is surrounded by an even layer of cortex, which is hyperechoic than the former [14, 16]. On abdominal radiographs, the kidneys are frequently seen bean shaped with the cranial pole of the right kidney located at the level of either the first or second lumbar vertebra [14]. For the left kidney, the cranial pole is located at the level of either the second or third lumbar vertebra [14]. Further, the right and left kidney's length have been reported to be 3.22 cm and 3.08 cm, respectively [14]. Moreover, the length and width of the kidneys are approximately 2 and 1.5, respectively, times the length of the second lumbar vertebra body [14]. On ultrasonography, the kidneys are ovoid and the right kidney measures 3.13 ± 0.2 cm in length and 2.54 ± 0.13 cm in width, whereas the left kidney measures 3.0 ± 0.23 cm in length and 2.26 ± 0.24 cm in width [14]. The pyriform urinary bladder is broader in male than female [14, 16]. The mean wall thickness of the urinary bladder measures 0.82 ± 0.34 mm on ultrasonography [14].

The large, conical prostate is partly subdivided into two lateral lobes [16]. The testis and epididymis are distinct [16]. Distally, the corpus cavernosum is continuous with the fusiform os penis [23]. The os penis is parallel and dorsal to the urethra and lacks any hint of a urethral groove [23]. It measures 1.4 ± 0.14 cm in length on radiographic examination [17]. The ovaries are small, ovoid located in a fossa on the lateral wall of the pelvis [16]. The fallopian tubes are coiled and the uterus is bicornuate with each cornu receiving at its apex the corresponding fallopian tube [16]. The external clitoris is enlarged and pendulous, tunneled by the urethra [23]. The os clitoridis is present within the corpus cavernosum of the glans clitoridis [23] and measures 0.38 ± 0.06 cm in length on radiography [17]. Moreover, Drea and Weil [23] reported the os clitoridis to be 43% the length and 24% the height of the os penis. The os clitoridis is parallel with the urethra and lies dorsal to the opening of the urethra [23].

3. Conclusion

The main limitation of this review is the limited information on the detail anatomy of the head of the ring-tailed lemur. Therefore, further studies describing the detail normal anatomy of the head of the ring-tailed lemur are recommended. Additionally, studies describing the normal computed tomographic (CT) and magnetic resonance imaging (MRI) anatomy of the ring-tailed lemur are needed since these imaging techniques are increasingly becoming available to veterinarians. Knowledge of the normal anatomy of individual species is important for accurate diagnosis and treatment of various diseases. This review has described the normal anatomy of the integumentary, musculoskeletal, respiratory, circulatory, digestive and urogenital systems of the ring-tailed lemur as a reference for clinical use and identification of the species

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