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ORIGINAL ARTICLE

Computed Tomographic Anatomy and Topography of the Lower Respiratory System of the Southern White-Breasted Hedgehog (*Erinaceus concolor*)

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Abstract

Objective- The aim of this study was preparing detailed anatomic images of the thoracic cavity of the southern white-breasted hedgehog using the non-invasive computed tomography (CT) technique.

Design - Descriptive study.

Animals - Five southern white-breasted hedgehog (*Erinaceus concolor*) which is a species native to the Middle East, Anatolia, Transcaucasia, and Iran. Since some people keep this animal as a domestic pet, their attendance at veterinary clinics is increasing.

Procedures - Five cases were examined with CT scan. Each hedgehog was anesthetized and positioned in ventral recumbency, and all scans were obtained on a two-detector scanner vertical to the longitudinal axes of the animal. After CT examination, the animals were euthanized to evaluate the anatomical structure of the thoracic cavity. Air was injected at the proximal part of the trachea to evaluate the structure of the lungs and trachea. CT images were compared with the dissected cases and were labeled according to anatomic assessment.

Results- Anatomic sections were studied and identified anatomic structures were matched with structures on corresponding CT images. Except for some blood vessels and details of the heart, most of the bony and soft tissue structures of the thorax discerned on anatomic slices could be found on matched CT images.

Conclusion and clinical relevance- The CT images from this study are intended as a reference for clinical CT imaging studies of the thoracic cavity of the southern white-breasted hedgehog and for interpreting lesions of the thorax and associated structures.

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1. Introduction

The southern white-breasted hedgehog (*Erinaceus concolor*) is a species native to the Middle East, Anatolia in Turkey, Transcaucasia, and Iran.[1,2] It used to be considered conspecific with the European hedgehog (*Erinaceus europaeus*);[3] However, more recent studies have viewed it as a distinct species.[1] These spiny animals have received special attention from pet owners. Their popularity in some countries such as the United States and Iran is increasing because these low-maintenance pets are enjoyable. By achieving a more in-depth understanding of their respiratory and cardiovascular systems, researchers can improve the domesticating process and captive rearing of these animals. As one of the most important body systems, the respiratory system is examined during routine physicals.

Computed tomography (CT) is an imaging technique which gives us an opportunity to review cross sections of the body in live animals. In veterinary medicine, although CT is mostly used for diagnostic purposes in small animals, in recent years CT also has been used as a non-invasive modality in non-clinical studies. Since a CT scan provides precise anatomic data which could be used as a reference for comparing images of abnormal cases, the current study attempts to examine the respiratory system of the European hedgehog using a CT scan.

2. Materials and Methods

Animals

Five sexually mature male southern white-breasted hedgehogs (weighing 753.4 ± 33.11 g) were examined. They were collected from different areas of Tabriz, Iran, between April and June (i.e., the mating season). The hedgehogs were fed with insects. They were allowed free access to water.

All animal procedures adopted in the present study were in accordance with the policy on humane care and use of laboratory animals and the Helsinki protocol (1975). They were approved by the research ethics committee in the University of Tabriz.

CT Examination

The hedgehogs were intramuscularly anesthetized with 25 mg/kg of ketamine 10% (Alfasan, Holland) after premedication with 1 mg/kg of diazepam (Caspian, Iran). Positioned in ventral recumbency, they were scanned using a two-detector scanner (Siemens Somatom Spirit), which was vertical to their longitudinal axes. The scanning parameters included rotation time (1 s), slice thickness (1mm), reconstruction interval (0.5-1 mm), pitch (1), X-ray tube potential (120 kV), and X-ray tube current (100 mA). The helical scans began at the tip of the mandible and covered the whole respiratory system. A dedicated computer workstation was used to review the CT images, which were examined in both bone and lung windows, with the window level (WL) and the window width (WW) adjusted to personal preferences for different parts. Furthermore, the 3D reconstruction images were reviewed in the pulmonary pattern for further investigation and an in-depth study of the respiratory system. The length of the trachea and the left and right bronchus were measured.

Anatomic Examination

After the CT examination was carried out, the hedgehogs were euthanized for medical reasons which were irrelevant to diseases of the respiratory system. First, they were opened up (Figure 1) and their respiratory organs were photographed in situ. The images of the excised respiratory organs were taken using a digital camera. The circumference, width, length, and weight of the lungs were recorded using a thread, ruler, and weighing scale (Shimadzu AW320, Germany).

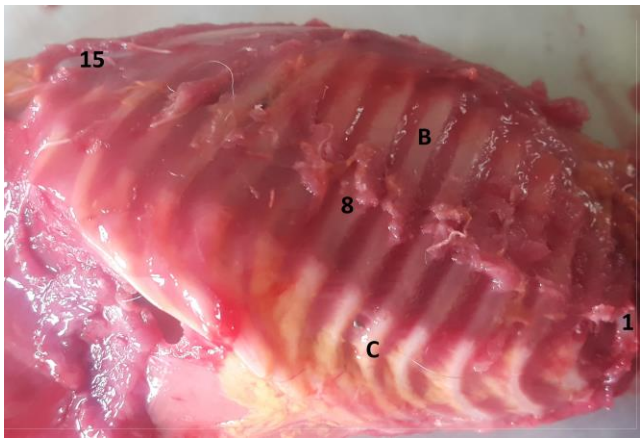

Figure 1. Lateral view of thoracic cavity of the hedgehog. B: bony part of the rib, C: cartilaginous part of the rib, 1: first rib, 8: eighth rib, 15: fifteenth rib.

3. Results

The CT images of the thoracic cavity could be found in Figures 2 and 3. The sections are shown from the thoracic inlet to the diaphragm in Figure 2 and from right side to left side in Figure 3. The anatomical dissection revealed

that the lungs are pale pink. The left lung had consisted of one piece only, was not lobulated, and had extended from the first to the fourteenth rib. The right lung was lobulated and had comprised cranial, middle (cardiac), caudal (diaphragmatic), and accessory lobes. The right cranial lobe had extended from the first to the fourth rib. The middle lobe was located in the fourth intercostal space. The right dorsal lobe had extended from the fourth to the twelfth rib. The whole accessory lobe had laid in the dorsal part of the heart and inclined toward the left and its ventral part had extended to the tip of the heart (Figure 4).

The measurements were taken during exhalation (Table 1). The lung was characterized by ventral and dorsal edges on both sides. It had consisted of lateral, diaphragmatic, and visceral surfaces. The diaphragmatic surface was formed by interconnecting the caudal surfaces of the left lung, the caudal lobe of the right lung, and the dorsal surface of the accessory lobe. The thymus had inclined completely toward the left and lied in the dorsal and cranial parts of the aorta. The heart had extended from the second to the seventh intercostal space and lied diagonally (in craniodorsal-caudoventral direction) on the sternum.

Table 1. Dimensions of the different parts of the lung in hedgehog (mm).

		Length	Width	Middle Diameter
Right lung	Cranial lobe	13.02	14.52	3.48
	Middle lobe	8.12	16.8	7.03
	Caudal lobe	24.85	20.67	8.64
	Accessory lobe	9.84	18.6	4.7
Left lung		40.89	19.49	7.27

The trachea was not fully cartilaginous and its c-shaped cartilages were interconnected by trachealis muscles in the dorsal region. The trachea had 14-16 cartilages. From the epiglottis to the tracheal bifurcation, the trachea was 41.44 mm long, where the cervical and thoracic tracheae were 26.72 and 14.72 mm long, respectively. It had entered the thorax and the mediastinum through the midline and bifurcates in the dorsal part of the heart. The trachea was 4.33 mm in diameter. The ribs number was 15; specifically, there were 10 true ribs, three false ribs, and two floating ribs.

4. Discussion

The anatomy of the lungs in Persian hedgehog was studied and compared with CT imaging results in this study for the first time. Computed tomography and 3D reconstruction have a role in the diagnosis of a wide range of diseases in a variety of animals.[4] One of the most important clinical contributions of CT examination is in relation to the pulmonary system. Craniocaudal and lateral radiographic views are normally used for detecting pulmonary diseases in chelonians.[5]

Thoracic CT images are commonly evaluated by use of a lung and a soft tissue (mediastinal) setting. Various structures of the respiratory tract are most distinct on the lung window. Still, for detection of pathologic processes, the lungs should be evaluated with lung and soft tissue windows to avoid missing lesions excluded by window settings.[6] We examined hedgehogs in both bone and lung windows. For a complete examination of the lungs, it is recommended to scan the patient in various positions, depending on the area of interest, because atelectasis and gravitational pulmonary-flow differences may alter the density of the dependent lung. Assisted suspended inspiration may also be needed to better assess overall lung density.[6] The hedgehogs were positioned in ventral recumbency in this study.

The definition of CT image patterns for most of the thoracic anatomical structures has been successfully achieved in other species, allowing setting up of baseline data to identify and interpret lesions. One of the main limitations of using these imaging techniques for diagnostic purposes is the low image resolution produced by small structures. However, as CT equipment improves so will the image resolution of all structures.[7] The cross-sectional images presented here contributes to the knowledge of the clinically relevant anatomy of the hedgehog thoracic cavity to aid in interpreting planimetric imaging techniques, such as CT and ultrasound.

The thoracic cavity is flattened on the sides and unevenly shaped in carnivores, equidae, ruminants,[8,9] and most rodents.[10,11] It is flattened on the top in mole rats.[12] The thoracic cavity of the hedgehog in the present study was laterally compressed.

The accessory lobe of the right lung is the smallest lobe in opossums,[13] rats,[14] polar foxes, and dogs.[15] In mole rats, the medial lobe is the smallest.[12] Although the medial and accessory lobes are large enough in hedgehogs, they are smaller than the other pulmonary lobes. Moreover, studies indicate that the right lung is larger than the left one and

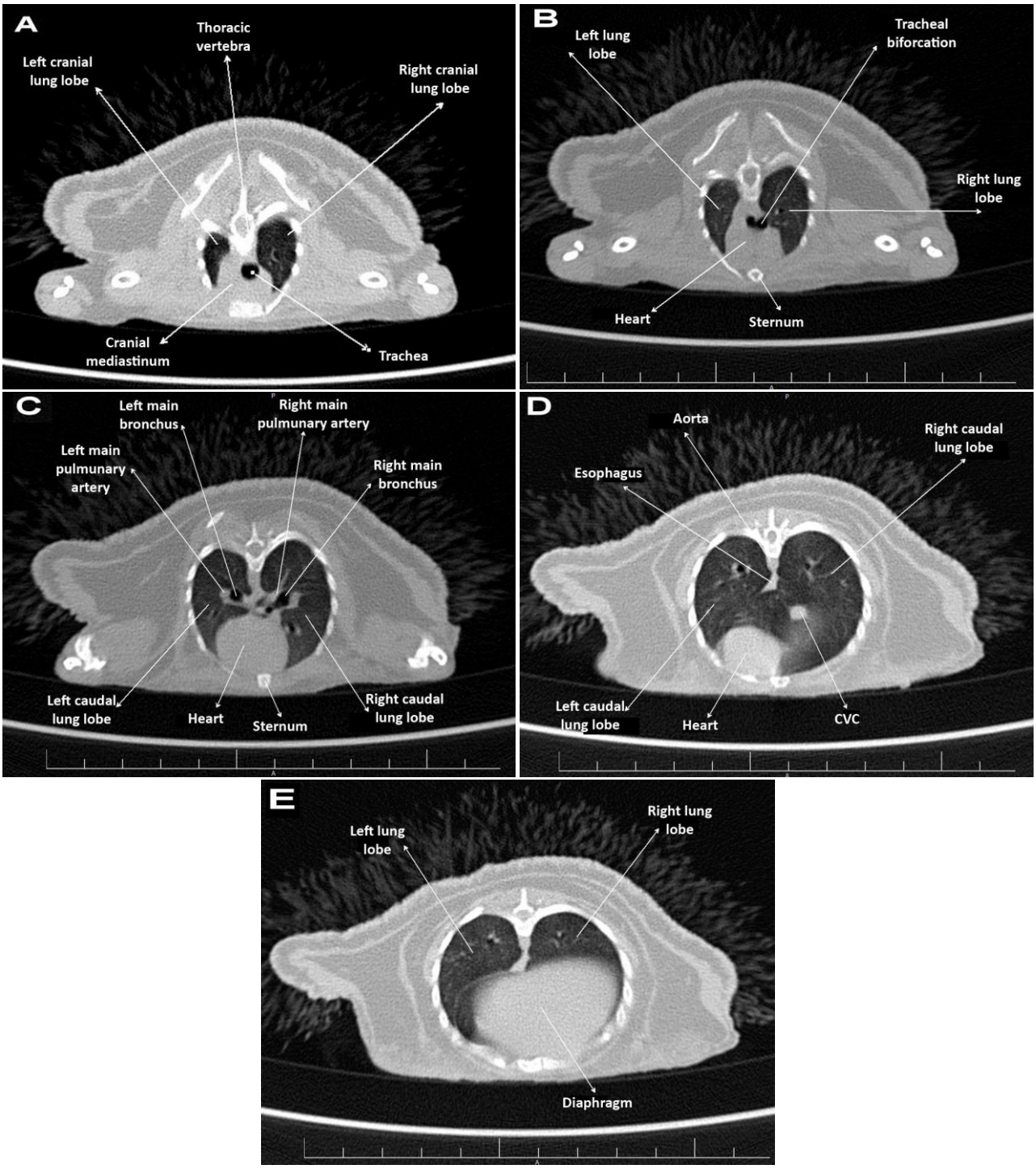

Figure 2. Serial CT images of the hedgehog thoracic cavity in axial plane from thoracic inlet (A) to the diaphragm (E).

the caudal lobe of the right lung is the largest pulmonary lobe. The same is true of hedgehogs.[13,14,16]

Reports demonstrate that the interlobar fissure in rodents is deep and the lobes of their right lung are completely separated.[13,16] Accordingly, the right lung consists of four lobes, namely cranial (lobus cranialis), medial (lobus medius), caudal (lobus caudalis), and accessory (lobus accessorius). The same division is true of the lobes in hedgehogs as well as opossums,[13] rabbits,[16] dogs, cats, sheep,[8] guinea pigs, and rats.[17] The left lung is divided into two lobes in rabbits,[16] one lobe in hazel dormice, mice, and pouched rats,[18] and three lobes in calves and carnivores.[8] As in rodents, the right lung in mole rats is divided into four lobes; however, the left lung is not specifically

lobulated. In this case, hedgehogs are similar to mole rats. The similarity in the number of pulmonary lobes can be attributed to the genetic closeness of the species. Furthermore, the difference between the species with respect to the lung lobe formation can be related to the evolution of terrestrial animals and marine mammals. In large mammals, the heart is situated in the lower ventral part of the middle mediastinum. As compared with the heart in humans, it has a more ventrally tilted long axis,[19,20] and a less-pronounced left-sided orientation.[11] Furthermore, the heart of most animals is elongated, thereby having a pointed apex. Dogs have an ovoid heart and a round, blunt apex.[21] Ruminants have a pointed apex and a cone-shaped heart. Sheep and pigs have a blunt apex,[22,23] which is medially oriented.[24] Rabbits have an elongated, cone-shaped heart and a pointed apex.[25] Their heart is similar to that of guinea pigs; however, the heart of these rodents is more proportional to the thoracic cavity in size. It occupies a large space in the thorax, leaving a small space for the lungs on each side. This is consistent with reports of other studies on the discrepancy in the ratios of the heart weight to the body weight, showing that the ratio is lower in adult pigs and sheep than adult dogs. It is approximately twice as much as the ratio in the above-mentioned animals.[21] Initial studies have demonstrated that the body weight is inversely proportional to the heart rate and directly proportional to the blood volume and heart weight.[20,26] The heart orientation in hedgehogs is similar to that in other animals. Their heart has a round apex.

Being enclosed by the pericardium, the heart of all mammals is located in the middle mediastinum.[24,11] In mammals, a thin pericardium is fixed to major arteries at the base of the heart and is attached to the diaphragm and sternum. Definitely, the degree of these attachments varies between species. In ruminants, the caudal part of the pericardium is attached to the sternum via the strong sternopericadial ligament and only the apex of the heart touches the sternum. In hedgehogs, the heart is enclosed by a thin pericardium but is not attached to the sternum or diaphragm at the base.

Given the results, it can be concluded that the right lung volume is larger than the left one in hedgehogs. The right lung is also longer, wider, and higher than the left one. Generally, the lungs extend from the second to the last rib

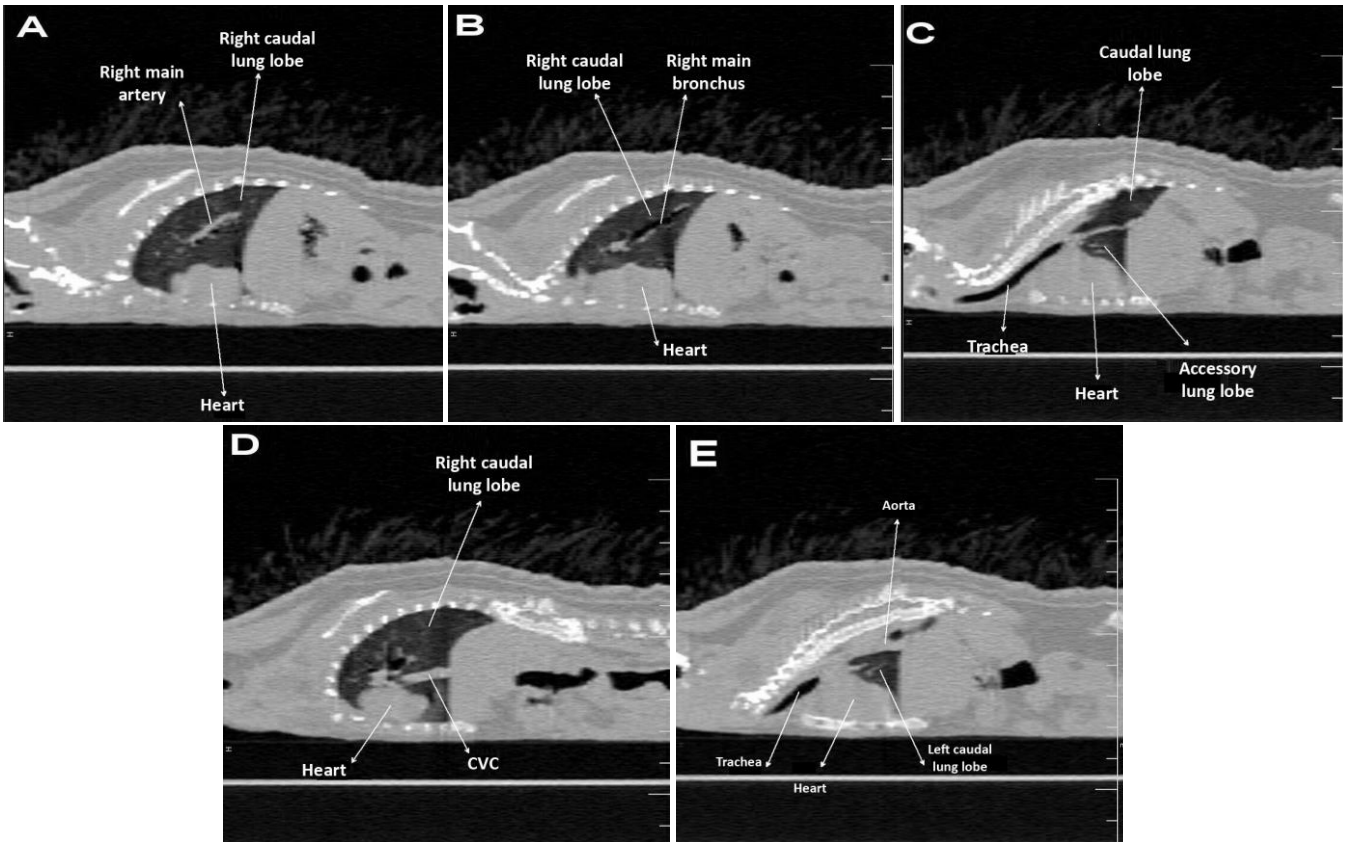

Figure 3: Serial CT images of the hedgehog thoracic cavity in parasagittal plane from right side of the body (A) to the left (E). In all of the sections, head is in the left and tail is in the right side.

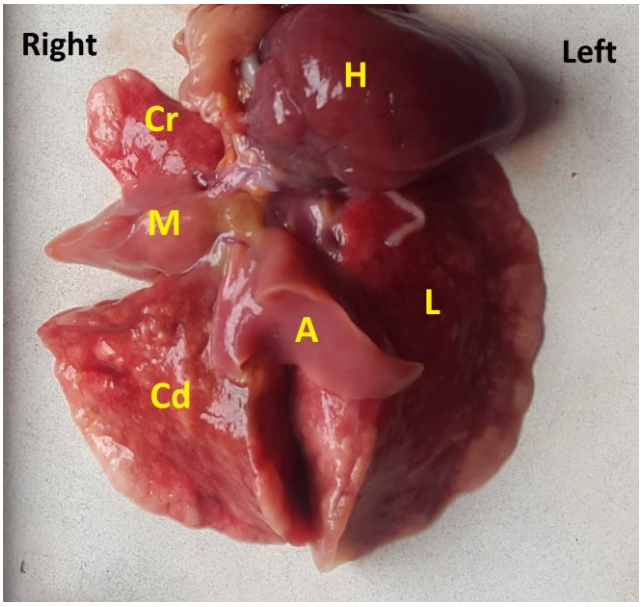

Figure 4: Thoracic viscera of the hedgehog. H: heart, Cr: cranial lobe, Cd: caudal lobe. A: accessory lobe, M: middle lobe, L: left lung.

but the right lung occupies somewhat more space caudally and cranially. After entering the thorax, the trachea tilts right and bifurcates there. The right bronchus is shorter than the left one and its volume is less. Extending caudodorsally, both the bronchi enter the lungs.

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Conflict of interests

The authors declare that they have no conflict of interest.

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چکیده

آناتومی و توپوگرافی مقطع‌نگاری رایانه‌ای دستگاه تنفسی تحتانی جوجه‌تیغی سینه‌سفید جنوبی

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هدف: هدف این مطالعه فراهم کردن تصاویر دقیق آناتومیکی از محوطهٔ سینه‌ای جوجه‌تیغی سینه‌سفید جنوبی با استفاده از روش غیرتهاجمی مقطع‌نگاری رایانه‌ای بود.

طرح مطالعه: مطالعه توصیفی.

حیوانات: پنج جوجه‌تیغی سینه‌سفید جنوبی که از گونه‌های بومی خاورمیانه، آناتولی، قفقاز و ایران است. ازآنجایی‌که برخی از مردم این حیوان را به‌عنوان حیوان خانگی نگهداری می‌کنند، ارجاع آن‌ها به درمانگاه‌های دامپزشکی رو به افزایش است.

روش کار: پنج جوجه‌تیغی با مقطع‌نگاری رایانه‌ای بررسی شدند. هر جوجه‌تیغی بی‌هوش شده و در حالت خوابیده به شکم قرار داده شد و تمام تصاویر عمود بر محور طولی حیوان با اسکنر ثبت شدند. پس از آزمایش با مقطع‌نگاری رایانه‌ای، حیوانات آسان‌کشی شدند تا ساختار آناتومیکی محوطهٔ سینه‌ای ارزیابی شود. برای بررسی ساختار ریه‌ها و نای، هوا از بخش قدامی نای به درون ریه‌ها تزریق شد. تصاویر مقطع‌نگاری رایانه‌ای با تصاویر آناتومیک مقایسه شده و بر پایهٔ بررسی آناتومیک، نام‌گذاری شدند.

نتایج: مقاطع آناتومیک مطالعه شده و ساختارهای آناتومیکی شناسایی‌شده با ساختارهای هم‌ارز در تصاویر مقطع‌نگاری رایانه‌ای تطبیق داده شدند. به‌جز برخی از عروق خونی و جزئیات قلب، بیشتر ساختارهای استخوانی و بافت نرم قفسهٔ سینه که در تشریح مشخص بودند، در تصاویر مقطع‌نگاری رایانه‌ای نیز دیده می‌شدند.

نتیجه‌گیری و کاربرد بالینی: تصاویر مقطع‌نگاری رایانه‌ای در این مطالعه می‌توانند به‌عنوان مرجعی برای مطالعات تصویربرداری مقطع‌نگاری رایانه‌ای محوطهٔ سینه‌ای جوجه‌تیغی سینه‌سفید جنوبی و نیز تفسیر ضایعات قفسهٔ سینه و ساختارهای مربوطه به کار روند.

واژه‌های کلیدی: جوجه‌تیغی، آناتومی، مقطع‌نگاری رایانه‌ای.