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Morphometric and 2D CT Anatomic Study of the Vertebral Column of the European Pond Turtle (*Emys orbicularis*)

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Abstract

Background: European pond turtle is one of the two species of freshwater turtles in Iran. Regarding clinical examinations and diagnostic imaging techniques, it is necessary to have complete anatomical information of the examined animal.
Objective: This study was done to provide complete morphometric and normal 2D computed tomographic scanning information of the vertebrae in European pond turtles.
Methods: Ten European Pond turtles were used in this study. CT-Scan images were taken from each anesthetized turtle. Morphometric parameters were measured in the CT-Scan images of the vertebral column.
Results: Atlas was the shortest of the cervical vertebrae, and the eighth cervical vertebra was shorter than the previous vertebrae. The articular surface of the caudal articular processes of the eighth cervical vertebra was bent, and these surfaces were almost vertical. Transverse process

width had remained constant in the cervical vertebrae. The transverse process was not observed in the dorsal vertebrae. 1st dorsal vertebra had a different shape than others.

Conclusions: The particular shape of the last two cervical vertebrae, especially the arched shape of the eight vertebrae. The seventh and eighth cervical vertebrae have the largest transverse distance between caudal articular processes seem to be essential features in cervical motion. The limited space of the caudal cervical vertebrae inside the shell chamber can be the reason for reduction in length of these vertebrae. It seems that the absence of spinous process in the seventh and eighth cervical vertebrae of the neck is related to their specific position in the neck retraction.

KEYWORDS

2D CT Anatomy, European pond turtles, Morphometry, Vertebral column

Introduction

The skeletal system is a very important compartment of the body, and usually, the position of other systems is defined according to this system. On the other hand, the elements of this system are used as a topographic guide in diagnostic imaging methods furthermore cases where the direct study of bones is necessary (Sisson and Grossman, 1975).

European pond turtle is one of the two species of freshwater turtles in Iran. No diagnostic imaging studies have been performed on the skeletal system of this species. However, similar studies have been done on other species. So far, various studies have been performed on different organs of the body in different species of turtles in the world, including joint radiological and anatomical works the following:

In 2006, Valente and colleagues examined radiographs of the neck and trunk of a *Caretta caretta*. They provided helpful indicators for identifying internal organs, including the bronchi, Coracoid bone, and Acetabulum (Valente *et al*., 2006). In 2007, Valente *et al*. studied the radiographical anatomy of the limbs of the *Caretta caretta* and described their normal radiographic profiles. The researchers also used 3D CT-Scans to describe this anatomy (Valente *et al*., 2007). In 2007, Valente *et al*. analyzed a CT-Scan of the vertebrae and coelomic cavity of the red sea turtle (*Caretta caretta*). They noted some essential points, such as the position of the various organs of the coelomic cavity compared to the carpus and vertebrae. One of the essential points of these researchers' study was that the trachea is bifurcated more cranially in other turtles than this species, which has been attributed to the inability of this species to contract its neck (Valente *et al*., 2007a). In 2019, Young *et al*. did a comparative limb bone scaling study in turtles (Young, *et al*. In 2019). In 2019, Ampaw *et al*. did a compressive study of the deformation and failure of trabecular structures in a turtle shell (Ampaw, *et al*. 2019). In 2017, Schachner *et al*. did a study on the pulmonary anatomy in a common snapping turtle (Schachner, *et al*. 2017). In 2019, Ricciardi *et al*. did a multidetector computed tomographic study of the lungs in the loggerhead sea turtle (Ricciardi, *et al*. 2019).

In 2012, Tyler and Walter studied topologically the relationship between the scapula and the rib cage. They found that the shoulder girdle was located inside the shell and in front of the rib cage (Tyler and Walter, 2012). In 2003, Sheil examined the morphology of bones during the embryonic period in the *Apolone spinifera* and compared it with another tortoise species. Adult tortoise bones have also been studied in detail in this study (Sheil, 2003). In 2009, Marcelo and colleagues studied bone morphogenesis during the embryonic period of the *Pelodiscus Sinensis*, a Chinese soft-shelled tortoise, focusing on the pattern and ossification sites. They found differences between this species and *Apolone spinifera* at different bone formation times (Marcelo *et al*., 2009). In 2004, Walter reviewed a comparison of the bone morphology of the

Testudines order, which includes wetland and terrestrial species, and their initial results suggest that ontogenic changes in skeletal structure may be one of the main reasons for differences within species of this order (Walter, 2004).

In 2005, Sheil & Greenbaum re-examined the formation time of different bones in the body of *Chelydra serpentine* and noted differences between species based on previous studies of other species (Sheil & Greenbaum, 2005). In 2007, Marcelo and colleagues studied the carpal and tarsal bones in 25 species of adult side-necked turtle and found greater diversity in manus and pes morphology (Marcelo *et al*., 2007). In 2020, Davari *et al*. studied the anatomical features of the lungs in the Caspian Pond Turtle by CT scan (Davari *et al*., 2020). In 2014, Zehtabvar *et al*. studied the anatomical features of the coelomic cavity in the European pond turtle by CT-Scan and radiography (Zehtabvar *et al*., 2014). In 2015, this researcher also studied the anatomical features of the non-respiratory organs of the European pond turtle coelomic cavity (Zehtabvar *et al*., 2015).

Regarding clinical examinations and diagnostic imaging techniques, it is necessary to have complete anatomical information of the examined animal, and it is necessary to consider these features in various studies. Also, in order to be able to interpret the injuries to the spine and the shell and to better understand the relative position of the internal organs of the body, normal radiographs and CT-Scans are suitable tools to achieve the above goals. This study analyzed the anatomical and 2D CT-Scan images of the vertebral column and compared the results with other available sources. By doing this study and similar studies, the first and necessary steps can be taken to identify better, preserve, and maintain this biological reserve. In addition, using morphometric measurements has attempted better to interpret the spine structure in the European pond turtle.

Materials and Methods

Individuals: Ten male adult European pond turtles (*Emmys orbicularis*) with an average weight of 450±45.22g. The specimens were kept in reptile suitable conditions for one week for to get used to the environment and return to normal conditions. During this period, whole fish carcasses (Black Sea sprat, *Clupeonella cultriventris*) were used to feed the turtles.

The identification keys provided in the references were used to select the turtles to separate the males from the females. In this species, the iris in males is reddish and orange, while it is almost yellow in females. The number of yellow spots on the head and neck of males is smaller and lesser than females. In addition, males have sunken plaster compared to females (Alinezhad, *et al*. 2019).

Computed Tomography (CT) Scanning:

The Siemens Somatom Spirit II CT-Scan machine was used to prepare images. After transferring the samples to the radiology department of the Small Animal Hospital of the Faculty of Veterinary Medicine, University of Tehran, the turtles were anesthetized by intramuscular injection of ketamine (25 mg/kg) and diazepam (1 mg/kg) (Carpenter and Marion, 2018).

Technical parameters for this imaging protocol were as follows: Rotation time, ls; slice thickness, 1mm; reconstruction interval, 0.5-1 mm; pitch, 1; X-ray tube potential, 120 kV; and X-ray tube current, 130 mA.

Appropriate Window width (WW) and Window level (WL) were selected to take each section's graph mentioned in each section's CT-Scan image results. Bone windows were used to check the images. The turtles were not euthanized after the study, and studies were performed on CT-Scan images. The turtles studied in this article are still alive and well at the time of writing.

Morphometric study:

After analyzing the CT scan images and identifying the different sections, the parameters were measured in the CT scan images of the vertebral column. The measured parameters are described in table 1. The results of the measurements are shown in tables 2-4. Morphometric mensuration from digital CT images was performed with Syngo MMWP VE40A software.

Statistical analysis:

Statistical analyses were done by SPSS software version 24.0. The descriptive statistics described by Mean±SD. Parameters were compared by running paired sample t-test analysis. A p-value less than 0.05 was statistically considered significant.

Results

2D CT- Scan: This species had eight cervical vertebrae, ten dorsal vertebrae, two sacral vertebrae, and twenty-five caudal vertebrae. The cervical vertebrae were highly mobile, and there were no cervical ribs. The dorsal vertebrae were immobile and fused. The Neural spines were fused and were integrated from the back with carapace Neural plate. The sacrum had two vertebrae. The tail also had twenty-five highly mobile caudal vertebrae (Figures 1).

The cervical region had eight vertebrae which each had a specific shape. The first and eighth vertebrae were significantly wider compared to their length.

Atlas (1st Cervical vertebra) had two neural arches, a centrum and an intercentrum. The cranial part of the vertebra included a cranial articular cavity to articulate with the occipital condyle. The ventral part of the centrum had a crest. The centrum had a foramen on either side (Lateral vertebral foramen) (Figures 1&2).

Axis (2nd Cervical vertebra) was more elongated than the atlas. The width was significant in the region of caudal articular processes. Transverse processes were located on both sides of the cranial surface of the centrum (Figures 1&2).

The third, fourth and fifth cervical vertebrae were very similar. The intervertebral foramen was formed between the vertebrae. This foramen was also formed between the second and third vertebrae. The transverse process was located in the cranial part of the vertebrae (Figures 1&2).

The sixth cervical vertebra was similar in appearance to the earlier vertebrae. The caudal articular processes were arched (Figures 1&2).

The general shape of the seventh vertebra was similar to the earlier vertebrae but wider. No spinous process was observed in this vertebra. Caudal articular processes were arched (Figures 1&2).

The eighth cervical vertebra had a unique shape. The length of the vertebra was shorter than the previous vertebrae. The articular surface of the Caudal articular processes was sharply indented and was bent, and these surfaces were almost vertical. Caudal articular processes were larger than cranial articular processes and had more arches than other vertebrae. No spinous process was observed in this vertebra (Figures 1&2).

The ribs, dorsal vertebrae, and dermal bones had formed a single bone called the carapace. The count of dorsal vertebrae was ten, to each of which a pair of ribs (costal heads) was attached (Figures 1&2).

1st dorsal vertebra had a different shape than the rest of the vertebrae, and its shape was significantly altered to articulate with the 8th cervical vertebra. A large articular surface was seen between the eighth cervical vertebra and the first dorsal vertebra. From the cranial part of the 1st dorsal vertebra's centrum, two delicate bone rods were elongated toward the second rib and finally attached to the cranial rim of the second rib head (Figure 1). The rest of the dorsal vertebrae were similar in appearance. It should be noted that the transverse process was not observed in the dorsal vertebrae.

The costal heads were connected proximally to the vertebrae and distally to the dermal bones. These plates were the costal dermal bones. The first and second costal heads were attached to the first costal dermal bone, and the ninth and tenth costal heads were attached to the eighth costal dermal bone (Figure 1). Due to the fusion of the dorsal vertebrae, there were no intervertebral foramens between them, but very small lateral vertebral foramens were observed.

The sacrum had consisted of two vertebrae. These vertebrae were not bonded to the carapace. Transverse processes in the first sacral vertebra had an articular surface for the Ilium (Figures 1&2).

The tail had twenty-five caudal vertebrae. Transverse processes became smaller in the caudal vertebrae. The length of the vertebrae towards the caudal was gradually reduced. (Figure 2).

Morphometric study: Results of morphometric studies of different parts of the vertebral column have shown in the 2-4 tables. As shown in Table 2, in the cervical vertebrae, the size difference between C1 and C2 was statistically significant concerning VBH, and the Vertebral body height had reduced ($p<0.05$). The difference in VBH size from C2 to C4 was not significant, and the vertebral body height had remained constant ($p>0.05$). The difference in VBH size from C4 to C6 was significant, and the Vertebral body height had reduced ($p<0.05$). The difference in VBH size between C6 and C7 was not significant, and the vertebral body height had remained constant ($p>0.05$). The difference in VBH size between C7 and C8 was significant, and Vertebral body height had increased ($p<0.05$).

In the cervical part of the vertebral column, the difference in VBL size from C1 to C8 was significant, and the vertebral body length had increased from C1 to C4 and had decreased from C4 to C8 ($p<0.05$). Atlas was the shortest of the cervical vertebrae.

Regarding TPW, the size difference from C1 to C8 was insignificant, and the transverse process width had remained constant ($p>0.05$). Concerning TDCA, the size difference between C2 and C3 was not statistically significant, and the transverse distance between caudal articular processes had remained constant ($p>0.05$). The difference in TDCA size between C3 and C4 was statistically significant, and the transverse distance between caudal articular processes had reduced ($p<0.05$). The difference in TDCA size from C4 to C6 was not significant, and the transverse distance between caudal articular processes had remained constant ($p>0.05$). The difference in TDCA size between C6 and C7 was significant, and the transverse distance between caudal articular processes had increased ($p<0.05$). The difference in TDCA size between C7 and C8 was not significant, and the transverse distance between caudal articular processes had remained constant (Table 2) ($p>0.05$). The seventh and eighth vertebrae have the largest transverse distance between caudal articular processes.

As illustrated in table 3, in the dorsal vertebrae, the size difference from D1 to D8 was not statistically significant concerning VBH, and the Vertebral body height had remained constant ($p>0.05$). The size difference between D8 and D9 was statistically significant, and the vertebral body height had increased ($p<0.05$). There was no significant difference between the VBH size of D9 and D10, and vertebral body height had remained constant ($p>0.05$). It should be noted that the difference in VBH size of C8 and D1 was statistically significant, and the vertebral body height had reduced ($p<0.05$).

Concerning dorsal vertebral VBL, as seen in Table 3, the size difference between D1 and D2 was statistically significant, and the vertebral body length had increased ($p<0.05$). The difference in VBL size from D2 to D7 was not significant, and the vertebral body length was constant ($p>0.05$). The difference in VBL size between D7 and D8 was statistically significant, and the vertebral body length had reduced ($p<0.05$). VBL size difference from D8 to D10 was not significant, and vertebral body length was constant ($p>0.05$). It should be noted that the difference in VBL size between D1 and C8 was not statistically significant, and the vertebral body length was constant ($p>0.05$).

As shown in Table 3, in the dorsal vertebrae, the size difference from D1 to D10 was not statistically significant for TDCA, and the transverse distance between caudal articular processes had remained constant ($p>0.05$). It should be noted that the difference in TDCA size between D1 and C8 was not statistically significant, and the transverse distance between caudal articular processes had remained constant ($p>0.05$).

As described in Table 4, in the sacral and caudal vertebrae, the size difference from S1 to Ca3 was not statistically significant regarding VBH, and the vertebral body height had remained constant ($p>0.05$). It should be noted that the difference in VBH size between S1 and D10 was not statistically significant, and the vertebral body height had remained constant ($p>0.05$).

As shown in Table 4, in the sacral and caudal vertebrae, the size difference from S1 to Ca1 was not statistically significant concerning VBL, and the vertebral body length had remained constant ($p>0.05$). It should be noted that the difference in VBL size of D10 and S1 vertebrae was statistically significant, and the Vertebral body length had reduced ($p<0.05$). The difference in VBL size between Ca2 and Ca1 was statistically significant, and length had reduced ($p<0.05$). The difference in size from Ca2 to Ca3 was not statistically significant, and the vertebral body length had remained constant ($p>0.05$).

As demonstrated in table 4, in the sacral and caudal vertebrae for TPW, the size difference between the S1 and S2 vertebrae was statistically significant, and the transverse process width had reduced ($p<0.05$). The difference in TPW size between Ca1 and S2 was statistically significant, and the transverse process width had reduced ($p<0.05$). The difference in TPW size between Ca1 to Ca3 vertebrae was not statistically significant, and the transverse process width had remained constant ($p>0.05$).

As shown in table 4, in sacral and caudal vertebrae, the difference between S1 and S2 vertebrae was not statistically significant regarding TDCA, and the transverse distance between caudal articular processes remained constant ($p>0.05$). It should be noted that the difference in TDCA size between S1 and D10 was statistically significant, and the transverse distance between caudal articular processes had reduced ($p<0.05$). The difference in TDCA size between Ca1 and s2 was significant, and the Transverse distance between caudal articular processes had reduced ($p<0.05$).

The difference in TDCA size between Ca1 and Ca3 was not significant, and the transverse distance between caudal articular processes has remained constant ($p>0.05$).

Discussion

Few studies have simultaneously investigated turtles' bones' anatomy and radiological appearance (Valente *et al*., 2006 and 2007). In some of these studies, the settings of the radiology device and the required voltage for preparing radiographs of the desired quality in sea turtles have been considered. According to the findings of these studies, in the anterior one-third of the carapace length, it is better to increase the kilo voltage and decrease it in the posterior one-third. It has also been suggested that it is best to use mammography films for more details in reptiles (Valente *et al*., 2006). In the present study, considering the used CT-Scan technique, the exact location of the bone structure was detectable, and the problems seen due to bone overlap on radiography were resolved.

In the present study, a large articular surface was seen between the eighth cervical vertebra and the first dorsal vertebra. In other words, since the head moves closer to or farther away from the body by moving these two vertebrae, the range of motion between the two vertebrae was wide, the joint surface is semicircular, and the contact surface between them was increased. In order to increase the range of motion between these two vertebrae, an arch has been created on the neck to allow the head to move as much as possible towards the shell. The cervical vertebrae of European ponds are very similar to those of *Apolone spinifera*, and both have eight highly mobile vertebrae (Sheil, 2003). However, in sea turtles, the first seven vertebrae of the neck are mobile, and the eighth cervical vertebra is fused to the Carapace. Since sea turtles cannot pull their heads toward the shell, they do not have a caudal arch of the neck. Their vertebrae's length is approximately equal, while the European pond turtle's caudal cervical vertebrae's length is reduced compared to the cranial cervical vertebrae. The particular shape of the last two cervical vertebrae, especially the arched shape of the eight vertebrae. The seventh and eighth vertebrae have the largest transverse distance between caudal articular processes seem to be essential features in cervical motion. It seems that the absence of spinous process in the seventh and eighth cervical vertebrae of the neck is related to their specific position in the neck retraction.

It seems that the limited space of the caudal cervical vertebrae inside the shell chamber can be the reason for reduction in length of these vertebrae (Zehtabvar *et al*., 2022). In a study, Valente *et al*. analyzed radiographs of the neck and trunk of the *Caretta caretta*. They developed a series of landmarks used to identify internal organs, such as the bronchi, sternum, and acetabulum. They mentioned that by viewing radiographic images, it is possible to determine a relationship between lateral and medial landmarks and to address the location of the coelomic cavity organs compared to the dermal plates of the carapace and the spine (Valente *et al*., 2006). In another study in 2007, Valente *et al*. analyzed the CT-Scan of the spine and the coelomic cavity of the Loggerhead Sea turtle (*Caretta caretta*). The researchers used anatomical slices to interpret the CT-Scan images better. They also determined the position of various organs of the coelomic cavity compared to the carapace and spine, which facilitated the interpretation of other diagnostic techniques such as radiography and sonography, and they also could ease biopsy and surgery. (Valente *et al*., 2007a). These researchers also noticed that the intervertebral and lateral vertebral foramen in the Loggerhead Sea turtle is similar to the European pond turtles.

Since the carapace is attached to the spine, carapace trauma can lead to spinal cord injury and neurological symptoms. Radiography is the best way to diagnose this fracture type in turtles. Radiographs taken by Valente *et al*. in 2006 from the trunk of a *Caretta caretta* showed significant overlap, especially in the cranial part of the Carapace, in such a way that nuchal bones, entoplastron, and vertebrae in this part were indistinguishable (Valente *et al*., 2006). As mentioned in the European pond turtle (*Emmys orbicularis*) Dorsal vertebrae, the structure of the transverse process was not observed; As mentioned in the references, the Transverse process has located in the thoracic region and attached to the intertransverse ligaments and muscles related to this region (König, *et al*. 2007). It seems that the lack of the Transverse process in the dorsal vertebrae of the current study turtle is related to the deformation of the ribs and the absence of the muscles and ligaments mentioned earlier in the coelomic cavity. In addition, it should be noted that the transverse process was observed in the cervical, sacral, and caudal vertebrae, and subsequently, the function of this structure was required in these parts. Transverse processes have created the widest width in the 1st sacral vertebra.

In 2015, Werneburg *et al*. studied the development of vertebrae shape and neck retraction in modern turtles with a geometric and morphometric approach. Modern turtles have neck retraction ability, one group is side-necked (*pleurodiran*), and the other is hidden-necked (*cryptodiran*). They have stated that the anatomical changes that led to the vertebral shapes of modern turtles have not been well understood yet. It has been mentioned that there is no correlation between the construction of formed articulations in the cervical centra and neck mobility. Excessive mobility between the vertebrae, together with a change in the shape of the vertebrae, has led to a more advanced ability to contract the neck (Werneburg, 2015). European pond turtle is a type of hidden-necked (*cryptodiran*) examined in our study. Our study examined the spine's structure so that several essential structural features and compatibility of the articular vertebrae were observed for the neck retraction process. It has been noted that in turtles that cannot retract the neck, the cervical vertebrae are compact and short. In general, it has been pointed out that using the morphometric method is one of the best methods to study the structural differences of cervical vertebrae in turtles (Werneburg, 2015). In our study, the morphometric method was used to analyze vertebrae changes in different areas.

It has been reported that the cervical vertebrae of *cryptodiran* are compressed dorsoventrally, which was almost observed in our study (Werneburg, 2015). Werneburg, in 2015 reported that the articular surface of the caudal articular process of the eighth cervical vertebra is almost vertical, which was also observed in our study. Concerning muscle adaptation involved in the movement, broad cervical vertebrae are more suitable for *cryptodiran*, whereas long cervical vertebrae in *pleurodires* (Werneburg, 2011).

Turtles have a group of HOX genes that influence the arrangement of axial skeletal components. Modifying some of these genes leads to sudden changes in development (Asadi Ahranjani, *et al*. 2016). The shape and position of the bones in the turtle's body can also be evaluated developmentally. It has been said that this position is similar to that of reptiles, amphibians, and early mammals. In 2012, Lyson *et al*. examined the relationship between the scapula and the rib cage topologically and found that the scapula in the turtles is placed vertically inside the shell and in front of the ribs. This position is also seen in early Amniotes such as amphibians, laying mammals, and reptiles of the *Lepidosaur* group. They concluded that turtles' developmental studies should be compared with laying mammals and reptiles of the Lepidosaurus group, which are more similar to turtles, instead of mice and chickens (Lyson & Joyce, 2012).

The neck of *cryptodires*, by contrast, is characterized by cervical joints that become increasingly more mobile towards the posterior. This observation may explain the orderly anterior-posterior shape patterning that their vertebrae form in morphospace (Herrel *et al*., 2008).

Regarding neck retraction, the main part of this movement is done with the retrahens capiti collique muscle, which is done ventrally to the cranium and ventrolaterally in all turtles (Herrel *et al*., 2008). Other muscles that function to revert the retracted neck are attached to the dorsal surface of the vertebrae in *cryptodires*, so the wide cervical vertebrae are a feature of this group of turtles. In the European pond turtle, we observed that the last two cervical vertebrae are not wider than the others, but the distance between the caudal articular process is greater than the earlier vertebrae.

According to the present study results, it can be concluded that the use of diagnostic imaging techniques such as CT-Scan in the study of the skeleton is beneficial. Because using this technique, facilitates determining the correct direction and position of the bones. In this study, the position of different parts of the European pond turtle spine in 2D CT-Scan images was determined, which can be used to diagnose various issues. The course of resizing different parts of the spine was also examined.

Due to the close relationship between the bones and the muscles and the effect of their tension on the shape and the formation of various processes on the bones, it is recommended to analyze the muscles of this species. It is also suggested to compare the skeleton of this species with other freshwater-dependent species and identify the differences between them.

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مطالعه مورفومتریک و سی تی آناتومی دو بعدی ستون مهره‌ها در لاک‌پشت برکه‌ای اروپایی (***Emys orbicularis***)

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چکیده

زمینه مطالعه: لاک‌پشت برکه‌ای اروپایی یکی از دو گونه لاک‌پشت آب شیرین ایران است. برای انجام معاینات بالینی و روش‌های تصویربرداری تشخیصی، داشتن اطلاعات کامل کالبدشناسی حیوان مورد معاینه ضروری است.

هدف: این مطالعه با هدف تامین اطلاعات کامل مورفومتریک و تصاویر سی تی اسکن دو بعدی طبیعی از مهره‌ها در لاک‌پشت برکه‌ای اروپایی انجام شد.

روش کار: مهره اطلس در بین مهره‌های گردنی کمترین طول را داشت و طول مهره هشتم گردن از مهره‌های قبلی خود کمتر بود. سطح مفصلی زایده مفصلی خلفی مهره هشتم گردن خمش شده و به صورت عمودی قرارگرفته بود. زایده‌های عرضی در مهره‌های پشتی مشاهده نشد. فاصله بین زواید عرضی در مهره‌های گردنی ثابت بود.

نتیجه گیری نهایی: شکل خاص دو مهره آخر گردنی، خصوصا قوس‌دار بودن مهره هشتم. مهره هفتم و هشتم گردن دارای بیشترین فاصله عرضی زوائد مفصلی خلفی هستند که به نظر می‌رسد برای حرکت گردن این حالت لازم است. دلیل کوتاه شدن طول دو مهره آخر گردن، فضای کم موجود در لاک برای آنها می‌تواند باشد. به نظر می‌رسد عدم وجود زائده خاری در مهره هفتم و هشتم گردن به دلیل موقعیت خاص آنها در جمع شدن گردن باشد.

واژه‌های کلیدی:

ستون مهره، سی تی آناتومی، لاک‌پشت برکه‌ای اروپایی، مورفومتری

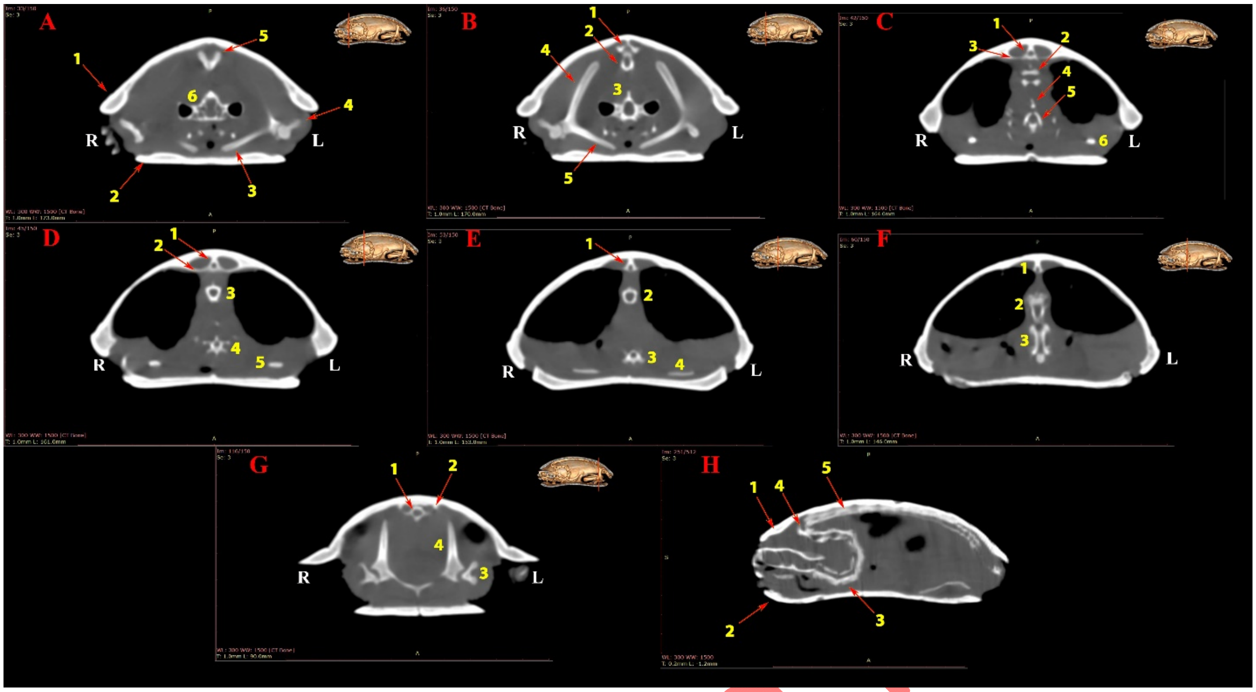

Figure 1. A-G: Transverse CT Images of the European pond turtle (Bone window), Different parts of the image are labeled. H: Sagittal CT Image (Bone window).

A: 1. Carapace, 2. Plastron, 3. Acromion, 4. Humerus, 5. 8th Cervical vertebrae, 6. Skull, **B:** 1. 1st Dorsal vertebrae, 2. 8th Cervical vertebrae, 3. Skull, 4. Scapula, 5. Acromin, **C:** 1st Dorsal vertebrae, 2. 7th Cervical vertebrae, 3. Head of the 1st rib, 4. Supra occipital process, 5. Atlas, 6. Coracoid, **D:** 1. 2nd Dorsal vertebrae, 2. Head of the 2nd rib, 3. 7th Cervical vertebrae, 4. Axis, 5. Coracoid, **E:** 1. 3rd Dorsal vertebrae, 2. 6th Cervical vertebrae, 3. 3rd Cervical vertebrae, 4. Coracoid, **F:** 1. 4th Dorsal vertebrae, 2. 5th Cervical vertebrae, 3. 4th Cervical vertebrae, **G:** 1. 10th Dorsal vertebrae, 2. Head of the 9th rib, 3. Femur, 4. Ilium, **H:** 1. Carapace, 2. Plastron, 3. Cervical part of the vertebral column, 4. 8th Cervical vertebra, 5. Dorsal part of the vertebral column

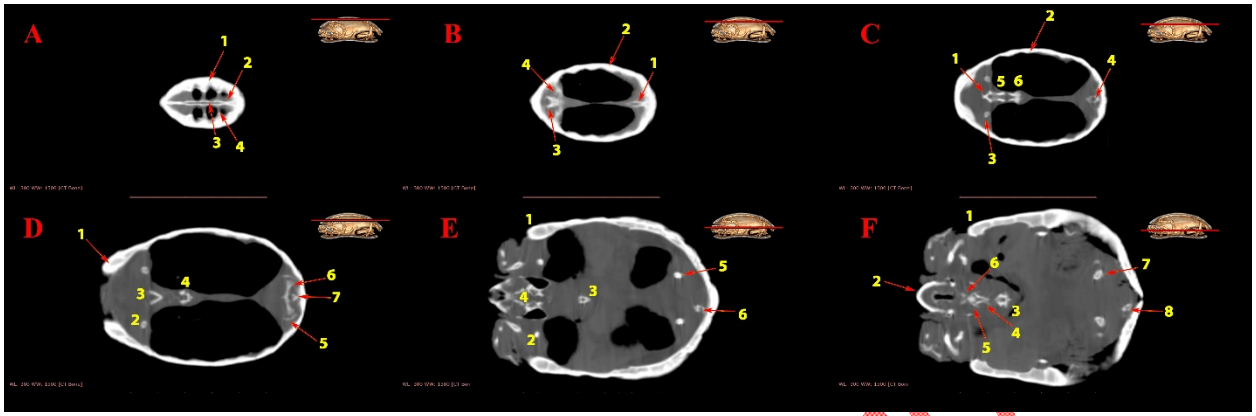

Figure 2. A-F: Dorsal CT Image of the European pond turtle (Bone window), Different parts of the image are labeled.

A: 1. Carapace, 2. Dorsal part of the vertebral column, 3. Vertebral canal, 4. Head of the rib, **B:** 1. Dorsal part of the vertebral column, 2. Carapace, 3. 1st Dorsal vertebra, 4. Head of the 1st Rib, **C:** 1. 8th Cervical vertebra, 2. Carapace, 3. Scapula, 4. Dorsal part of the vertebral column, 5. 7th Cervical vertebra, 6. 6th Cervical vertebra, **D:** 1. Carapace, 2. Scapula, 3. 7th Cervical vertebra, 4. 5th Cervical vertebra, 5. Ilium, 6. 1st Sacral vertebra, 7. 2nd Sacral vertebra, **E:** 1. Carapace, 2. Scapula, 3. 4th Cervical vertebra, 4. Skull, 5. Ilium, 6. Caudal vertebrae, **F:** 1. Carapace, 2. Mandible, 3. 3rd Cervical vertebra, 4. Axis, 5. Atlas, 6. Skull, 7. Ilium, 8. Caudal vertebrae