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Computed Tomographic and Morphometric Study of Cervical Vertebrae in Healthy White New Zealand Rabbit (*Oryctolagus Cuniculus*)

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Abstract

BACKGROUND: Nowadays, use of rabbits in research as laboratory animals is quite prevalent, however imaging modalities for producing anatomical illustrations are rare. Computed tomography (CT) is a nonaggressive modality which provides more anatomical detailed data.

OBJECTIVES: This study aimed to create a plenary and exact deliniation and morphometric evaluation of cervical vertebrae in rabbits.

METHODS: A CT scanner with two detectors was used in this study. Several parameters were measured in 10 healthy, adult female white New Zealand rabbits and the results were evaluated.

RESULTS: Some parameters including VBH, SCH, PDL, PDW, VBL, EPH, and EPW had no significant difference through cervical vertebrae but other parameters such as SPH, TPL, TPW, SPA, and TPA were significantly different. In the fifth cervical vertebrae, transverse process had three parts, as well as having a big transverse foramen while in the sixth vertebra, transverse process resembled a wide plate

CONCLUSIONS: VBH had an invariable measure from the second to seventh cervical vertebrae. SPH had an invariable measure from the second cervical vertebra to the sixth one, then once more it increased at the location of the seventh cervical vertebra and was invariable up to the first thoracic vertebra. This study presents a complete and precise description and morphometric evaluation of cervical vertebrae in rabbits using CT scan. As an important feature of this study, no specimen was killed and anatomical studies were performed using the CT scan technique.

KEYWORDS: Anatomy, Cervical vertebrae, Computed tomography, Morphometry, Rabbit

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Introduction

Nowadays, use of rabbits in research as laboratory animals is quite prevalent, however imaging modalities for producing anatomical illustrations are rare. The vertebral column is one of the most important parts of the skeleton of the rabbits that can be injured easily. Diagnostic imaging techniques are very useful in finding vertebral column injuries, however anatomical data (morphological and morphometric) are needed for this purpose. The cervical region is one of the important parts of vertebral column, consisting seven vertebrae (Worth, 2019; Riggs, 2016; Zehtabvar *et al.*, 2015).

Computed tomography (CT) scan is a nonaggressive modality which provides more detailed data for the evaluation of vertebral column and is a good diagnostic aid for different skeletal and neurological diseases. An accurate diagnosis of abnormalities requires sufficient knowledge around normal situation of these structures.

CT scan is one of the most practical diagnostic methods used in small animal orthopedic purposes. In 2010, Sheng and colleagues evaluated vertebral columns of large animals and compared them with that of human (Sheng, *et al.*, 2010). Jeffcott *et al.* (1979) evaluated anatomical radiography of thoracic and lumbar vertebra in horses. Furthermore, Cotterill *et al.* (1986) compared thoracic- lumbar vertebrae of cows with those of humans. Our study was based on the measurements of vertebrae and evaluation done on 2D and 3D CT scan. For many reasons, there is a possibility of traumatic injury to the spinal canal and intervertebral disc and these factors may contribute to the poor function of vertebral column. Nowadays, diagnostic imaging methods which are in use for numerous purposes are one of the best ways of evaluating the organs of body. These methods are also used for imaging the laboratory animals such as rabbits. One of these methods is CT scan which is remarkably useful for skeletal evaluations (Varga, 2014). Using CT scan, Zotti, Banzato, and Cozzi (2009) evaluated the anatomy of the neck, thorax, and abdomen in four rabbits (two males and two females). Van Caelenberg *et al.* (2010) evaluated the skull and the related soft tissues in rabbit with CT scan. These researchers reported that continuous growth of the teeth in rabbits predisposed them to dental diseases to which cheek teeth are mostly prone. In 2012, De Rycke *et al.* declared that dental disease is very common in rabbits, and radiographic techniques are useful in the diagnosis of these diseases. On the other hand, they displayed that because of the small size of skull in rabbits and superimposition of structures in radiographic images, CT could be a better modality for the evaluation of skull and teeth. They further stated that micro CT has higher quality though they are expensive. According to their reports, like Helical CT, micro CT provides lower soft tissue contrast than the CT technique (Van Caelenberg, *et al.*, 2010). CT is one of the fastest and accurate methods for the study of vertebral columns in small animals. CT scan is also regarded as one of the best methods for topographic studies. While some use this technique in their anatomical studies, some others prefer ultrasonography and radiography. One of the advantages of these techniques is the investigation of anatomical structures in live animals (Zehtabvar, *et al.*, 2014, 2016, 2018, 2019).

In contrast to the frequent uses of rabbits in different areas of study, the normal structure of different parts of cervical vertebrae especially normal morphometric parameters have not been studied by CT. In this study, a thorough description and morphometric evaluation of cervical vertebrae was presented in rabbits using CT scan, and several parameters were measured in cervical vertebrae.

Materials and Methods

Animals

Ten adult female white New Zealand rabbits (*Oryctolagus cuniculus*) with an average body weight of 1.95±0.5 kg were evaluated in this study. All rabbits were in good health.

Computed Tomographic Study

Rabbits were first anesthetized using ketamine (35 mg/kg body weight, IM) and xylazine (4 mg/kg body weight, IM) (Carpenter, Marion, 2017).

A CT Scanner with two detectors (SOMATOM Spirit, Siemens, Germany) was used in this study. Images were taken in ventral recumbency. The images were taken as transverse and perpendicular to vertebral column and in 2-mm slices. Technical factors for CT were as follows: rotation time, 1 s; slice thickness, 1 mm; reconstruction interval, 0.5–1 mm; pitch, 1; X-ray tube potential, 120 kV; and X-ray tube current, 130 mA. In images produced in CT scan, several structures of cervical vertebrae were evaluated and different parts were named. For evaluating each part, proper window level (WL) and window width (WW) were chosen for the evaluation of bone window and thorax (chest) window.

Morphometric Study

Morphometric mensuration of CT images was done with Syngo MMWP VE40A software. The measured parameters are shown in Tables 1-3. The results of measured parameters were analyzed by SPSS version 16.0 (SPSS Inc. Chicago, IL. USA). Paired sample t test was used to compare the values of means (P>0.05). Due to the structural characteristics of some vertebrae, some parameters were not measured in the cases referred to in the tables.

Table 1. Anatomical parameters

Parameter	Abbreviation*	Description
Vertebral body height	VBH	Distance between the base of vertebra to vertebral canal in transverse view
Spinous process length	SPL	Distance between base of spinous process to apex of process in sagittal view
Spinous process height	SPH	Distance between base of spinous process to apex of process in transverse view
Transverse process length	TPL	Distance between the base of transverse process to extremity of process in transverse view
Transverse process width	TPW	Distance between left extremity of process to right extremity in transverse view
Spinous process angle	SPA	The angle between spinous process with horizontal line in sagittal view
Transverse process angle	TPA	The angle between transverse process with horizontal line in transverse view
Spinal canal depth	SCD	Distance between proximal extremity of vertebral canal to distal extremity of vertebral canal in transverse view
Spinal canal width	SCW	Distance between left extremity of vertebral canal to right extremity of vertebral canal in transverse view
Pedicle length	PDL	Distance between proximal extremity of pedicle to distal extremity in transverse view
Pedicle width	PDW	The width of pedicle in transverse view
Vertebral body length	VBL	The length of vertebral body in sagittal view

Parameter	Abbre-viation*	Description
Endplate width	EPW	The width of end plate in transverse view
Endplate height	EPH	The height of end plate in transverse view

*Notes about abbreviations: in rabbits like other domestic animal, atlas has no prominent spinous process and also because of the presence of wing instead of transverse process, this parameter is named as WPL and also for transverse process width in this vertebra, WPW is used instead of TPW. In rabbits like other animals, atlas has no prominent pedicle and endplate. In the first to sixth cervical vertebra in sagittal view, because of the small size of spinous process, in this vertebrae SPA was unmeasurable.

Table 2. Computed tomographic measurements of cervical vertebrae of rabbit (Mean ± SD in cm and degree*)

Cervical vertebrae	TPA* WPA(C1, S)	SPA*	TPW WPW(C1, S)	TPL WPL(C1, S)	SPH	VBH
C_1	7.9±0.4a	-	2.7±0.08a	1±0.07b	-	-
C_2	29.3±0.9b	-	1.2±0.06b	0.4±0.04a	0.6±0.05a	0.3±0.04a
C_3	24.1±0.7b	-	1.4±0.1b	0.5±0.04a	0.3±0.03a	0.3±0.01a
C_4	24±0.3b	-	1.6±0.2b	0.6±0.06a	0.3±0.03a	0.3±0.02a
C_5	13.6±5.06c	-	1.9±0.08c	0.7±0.06a	0.4±0.06a	0.3±0.02a
C_6	11±6.06c	-	1.9±0.08c	0.7±0.04a	0.4± 0.1a	0.3±0.03a
C_7	12.8±0.5c	69.5±0.5a	2±0.1c	0.7±0.05a	0.9±0.2ba	0.3±0.04a

The different letters (a,b,c) in each column, represent significant difference between vertebrae (n=10, *P*<0/05)

Table 3. Computed tomographic measurements of cervical vertebrae of rabbit (Mean ± SD in cm and degree*)

Cervical vertebrae	EPH	EPW	VBL	PDW	PDL	SCW	SCH
C_1	-	-	-	-	-	1±0.05a	0.5±0.05a
C_2	0.3±0.01a	0.6±0.3a	1±0.6a	0.2±0.04a	0.5±0.05a	0.5±0.05b	0.5±0.06a
C_3	0.2±0.006a	0.7±0.04a	0.9±0.05a	0.2±0.03a	0.3±0.07a	0.5±0.04b	0.4±0.02a
C_4	0.3±0.01a	0.7±0.05a	0.8±0.04a	0.3±0.04a	0.3±0.06a	0.5±0.06b	0.4±0.08a
C_5	0.3±0.03a	0.7±0.07a	0.8±0.06a	0.3±0.02a	0.3±0.05a	0.6±0.05b	0.4±0.04a
C_6	0.3±0.04a	0.6±0.07a	0.8±0.12a	0.4±0.04a	0.4±0.08a	0.6±0.03b	0.4±0.07a
C_7	0.3±0.05a	0.7±0.1a	0.8±0.06a	0.4±0.04a	0.4±0.08a	0.6±0.02b	0.4±0.04a

The different letters (a,b) in each column represent significant difference between vertebrae (n=10, *P*<0/05)

Results

Morphological Results

Atlas (C1)- Vertebral body and spinous process were not present in this vertebra, and transverse process changed to two wide horizontal wings (Figure 1). Atlantal fossa was in both right and left parts of ventral surface of atlas wings. Furthermore, in cranial part of wing, alar notch was observed and in the caudal part of wing, there were transverse foramens (Figure 1).

Axis (C2) - This vertebra had a slender spinous process which was located dorsally and met the arch of atlas. In cranial extremity of this vertebra in rabbits, there was cranial articular process which becomes dense and lies in fovea dentis of atlas. Dens in rabbits was round and filamentary and was located cranioventrally and continued to ventral surface of atlas (Figures 1, 2, 3).

Typical cervical vertebrae (C3, C4, C5) - In C3 and C4 in rabbits, transverse processes had two parts. Spinous process in these vertebrae was short and transverse process was seen clearly. In C5, transverse process had three parts, as well as having a big transverse foramen (Figures 3, 4, 5).

Sixth cervical vertebra (C6) - In C6, transverse process had three parts, but its two ventral portions had a distinct wide plate (Figures 6 and 8).

Seventh cervical vertebra (C7) - In C7, spinous process was a little higher than that in other cervical vertebrae. Furthermore, caudal part of the body in each side had an articular surface for rib articulation and this vertebra had a short body. Spinous process in C7 was more prominent (Figure 7).

Morphometric Results

The results of measurements and statistical analysis are shown in Tables 2 and 3. Significant or non-significant differences in measured parameters are shown in Tables 2 and 3.

VBH had an invariable measure from C2 to C7. SPH had an invariable measure from C2 to C6, then again it increased at C7. TPL was the longest in C1 and decreased at C2 and was invariable up to the location of C7. TPW was the widest in C1 and then it decreased at C2 and was invariable up to C4. It once more increased at C5 and was invariable up to the location of C7. TPA was the lowest at the location of C1. It increased at C2 and was invariable up to C4, then again it decreased at C5 and was invariable up to C7. SCW was the widest in atlas between all cervical vertebrae, then it was invariable from C2 up to C7. PDL had different measurements from C2 up to C7. PDW had an invariable measure from C2 up to C7. VBL had different measures from C2 up to C7. EPW had different measures from C2 up to C7, and EPH had an invariable measure from C2 up to the location of C7. SPA was measured just in C7 and was not compared with that of other vertebrae.

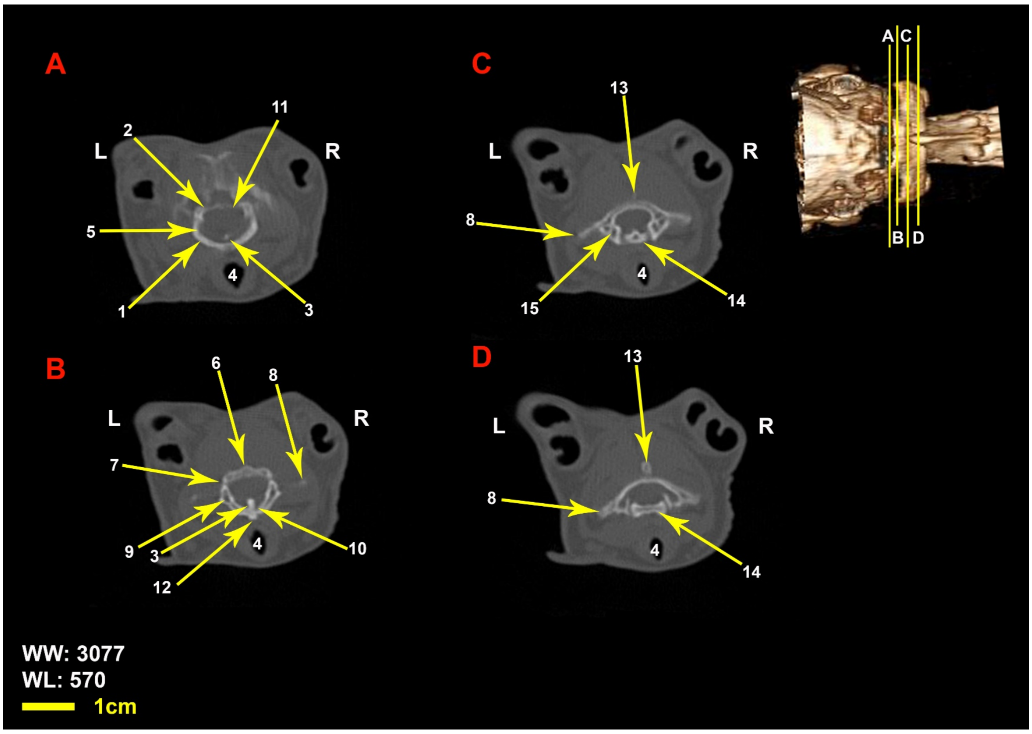

Figure 1. Transverse Computed tomography images (bone window) of Atlas and Axis in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1. Ventral arch, 2. Dorsal arch, 3. Dens of axis, 4. Trachea, 5. Cranial articular surface, 6. Dorsal tubercle, 7. Lateral vertebral foramen, 8. Wing of atlas, 9. Transverse foramen, 10. Fovea dentis, 11. Alar foramen, 12. Ventral tubercle, 13. Cranial part of axis, 14. Axis, 15. Pedicle of axis.

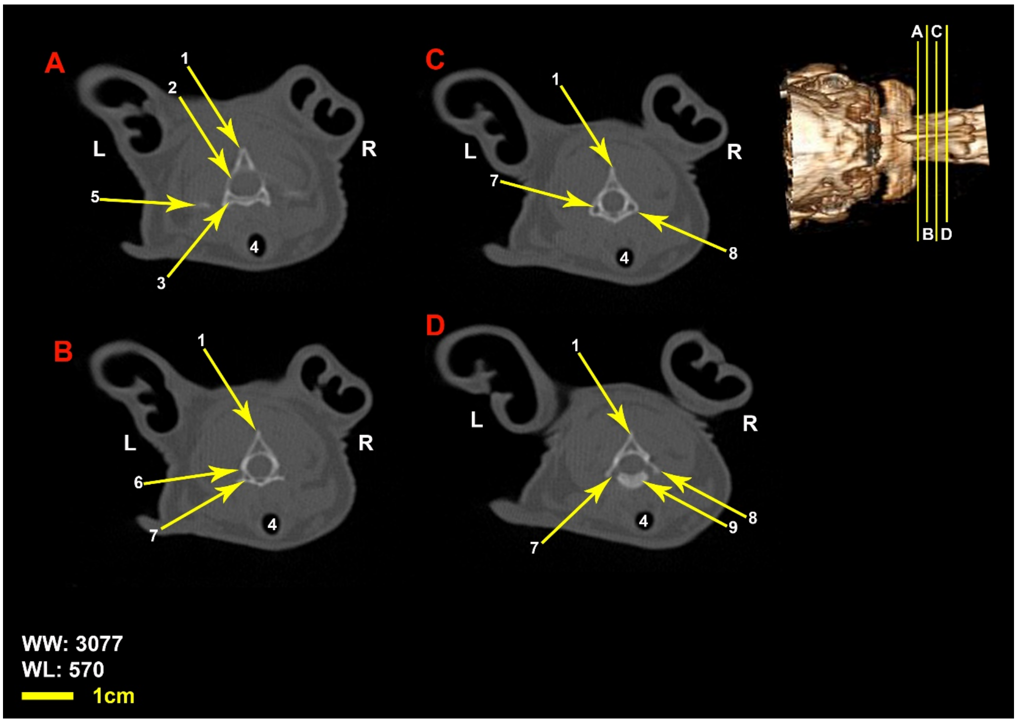

Figure 2. Transverse Computed tomography images (bone window) of Axis in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1.spinous process of axis, 2. Lateral vertebral notch, 3. Cranial articular surface, 4. Trachea, 5. Wing of atlas, 6. Pedicle of axis, 7. Transverse foramen, 8. Transverse process, 9. Body of axis

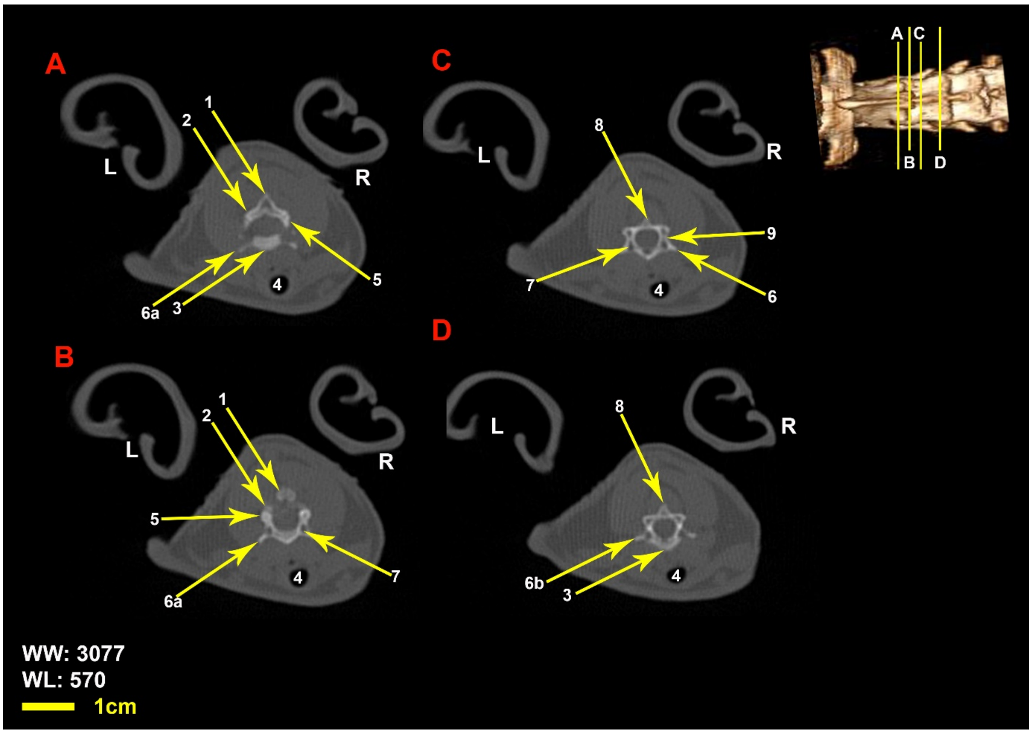

Figure 3. Transverse Computed tomography images (bone window) of the second and third cervical vertebrae in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1. spinous process of axis, 2. Caudal articular process of axis, 3. Body of the third vertebra, 4. Trachea, 5. Cranial articular process of the third vertebra, 6. Transverse process, 6a. cranial part of transverse process, 6b. dorsal tubercle, 7. Transverse foramen, 8. Spinous process of the third vertebra, 9. Caudal part of transverse process.

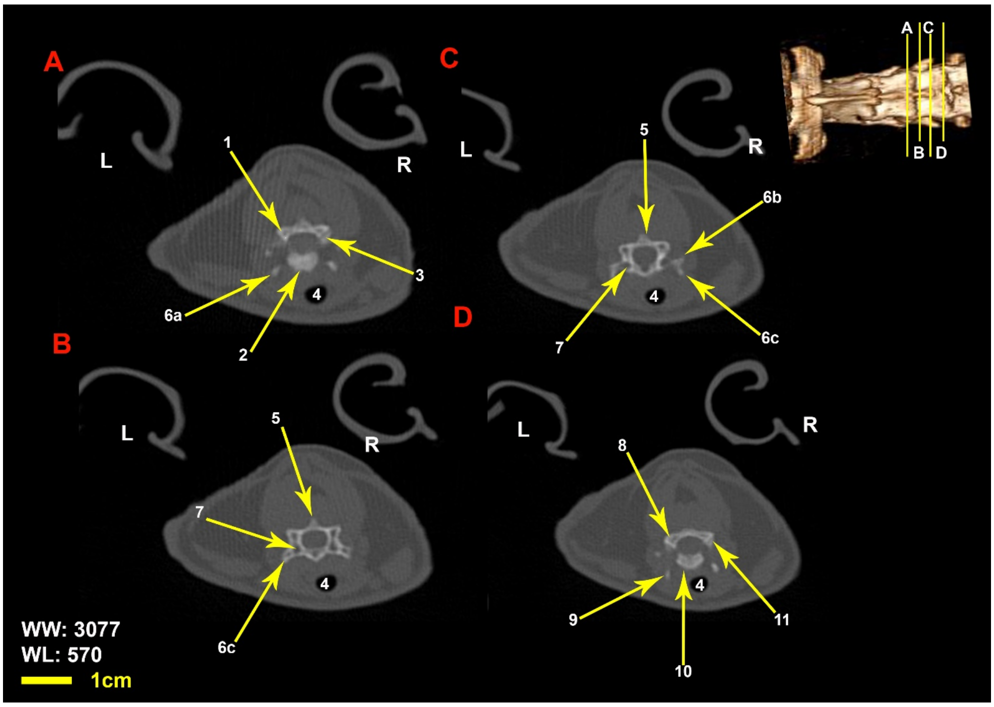

Figure 4. Transverse Computed tomography images (bone window) of third, fourth and fifth cervical vertebrae in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1. caudal articular process of the third vertebra, 2. Body of the fourth vertebra, 3. Cranial articular process of the fourth vertebra, 4. Trachea, 5. Spinous process of the fourth vertebra, 6a. cranial part of transverse process, 6b. dorsal tubercle of the fourth vertebra, 6c. caudal part of transverse process, 7.transverse foramen of the fourth vertebra, 8.caudal articular process of the fourth vertebra,9. Cranial part of transverse process of the fifth vertebra, 10. Body of the fifth vertebra, 11. Cranial articular process of the fifth vertebra.

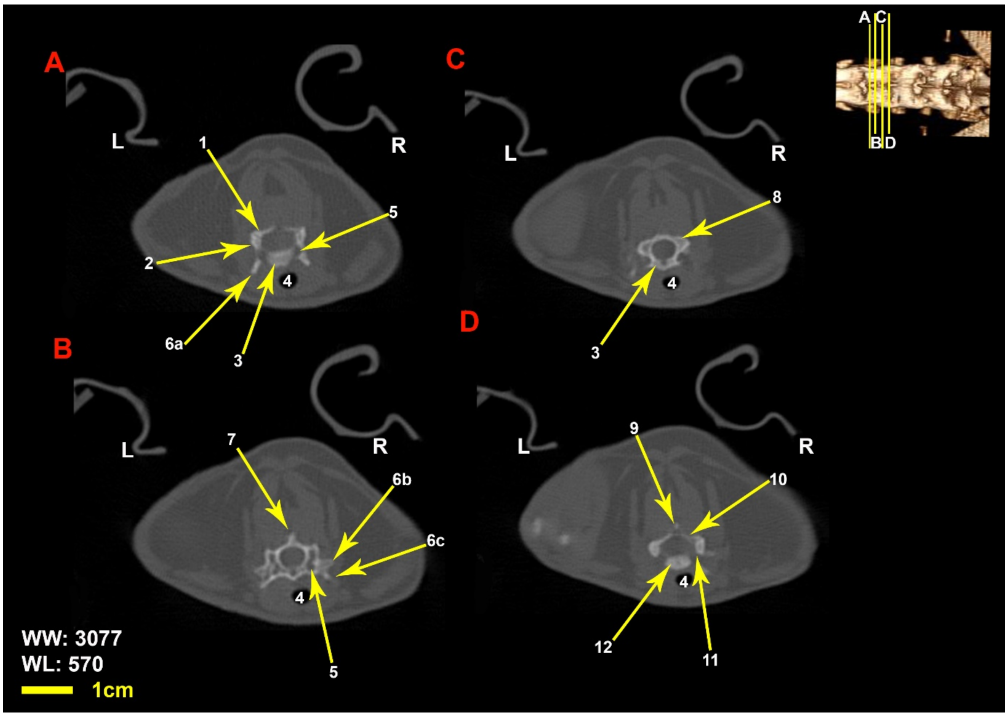

Figure 5. Transverse Computed tomography images (bone window) of fifth and sixth cervical vertebrae in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1.caudal articular process of the fourth vertebra, 2. Cranial articular process of the fifth vertebra, 3. Body of the fifth vertebra, 4. Trachea, 5. Transverse foramen of the fifth vertebra, 6a, cranial part of transverse process, 6b, dorsal tubercle, 6c. caudal part of transverse process of fifth vertebra, 7. Spinous process of the fifth vertebra, 8. Lamina, 9. Spinous process of the sixth vertebra, 10. Caudal articular process of the fifth vertebra, 11. Cranial articular process of the sixth vertebra, 12. Body of the sixth vertebra.

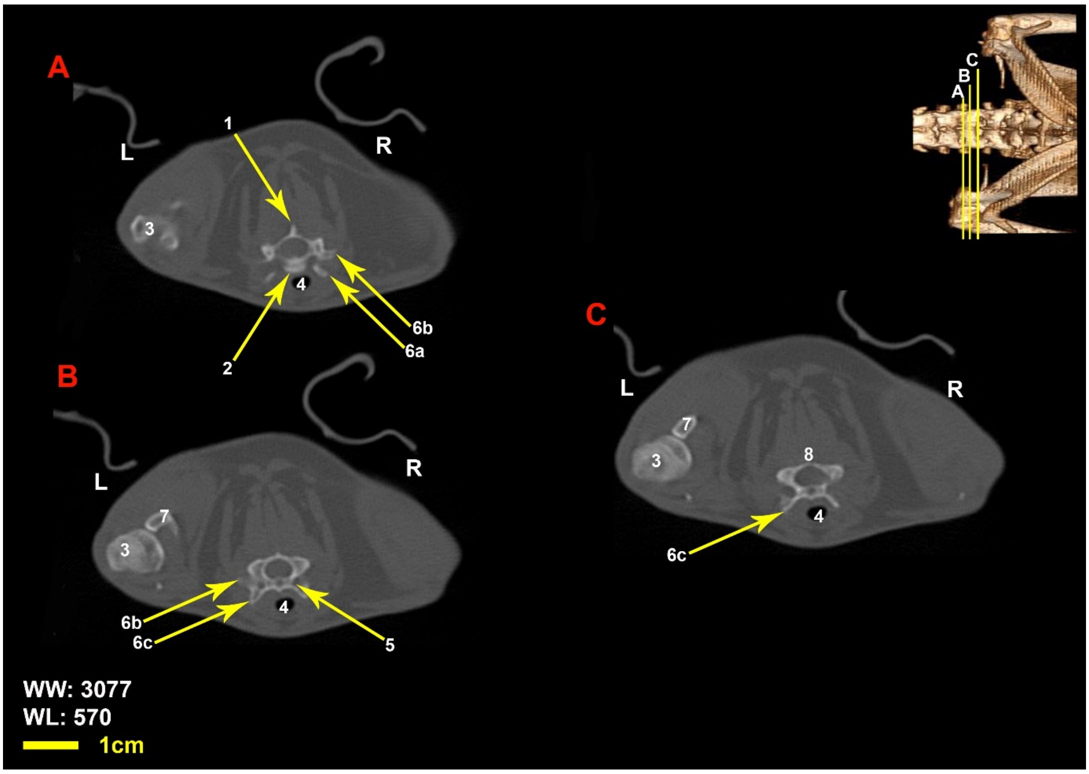

Figure 6. Transverse Computed tomography images (bone window) of the sixth cervical vertebrae in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1. Spinous process of the sixth vertebra, 2. Body of the sixth vertebra, 3. Humerus, 4. Trachea, 5. Transverse foramen, 6. Transverse process, 6a. cranial part of the sixth vertebra, 6b. dorsal tubercle of the sixth vertebra, 6c. caudal part of transverse process of the sixth vertebra, 7. Scapula, 8. Lamina of the sixth vertebra.

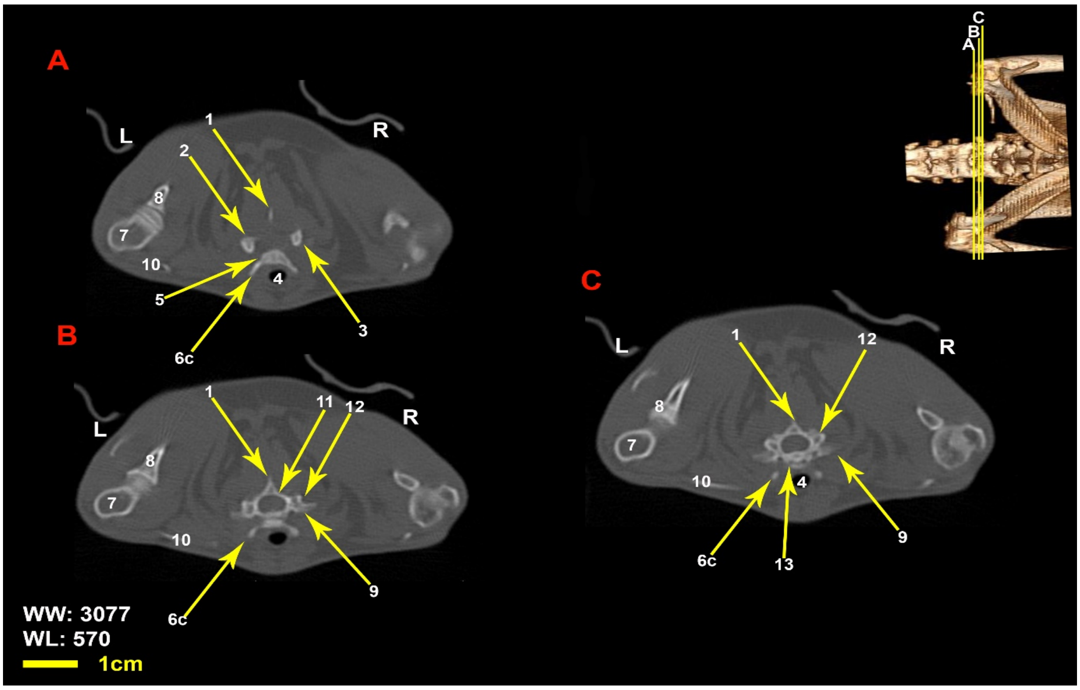

Figure 7. Transverse Computed tomography images (bone window) of the sixth and seventh cervical vertebrae in rabbit, the picture at the right top of this figure shows the section of transverse CT images (3D reconstruction image, Osseous-Shaded-vp).

1.spinous process of the seventh vertebra, 2. Caudal articular process of the sixth vertebra, 3. Cranial articular process of the seventh vertebra, 4. Trachea, 5. Body of the sixth vertebra, 6c. caudal part of transverse process of the sixth vertebra, 7. Humerus, 8. Scapula, 9. The first rib, 10. Clavicle, 11. Lamina of the seventh vertebra, 12. Transverse process of the seventh vertebra, 13. Body of the seventh vertebra.

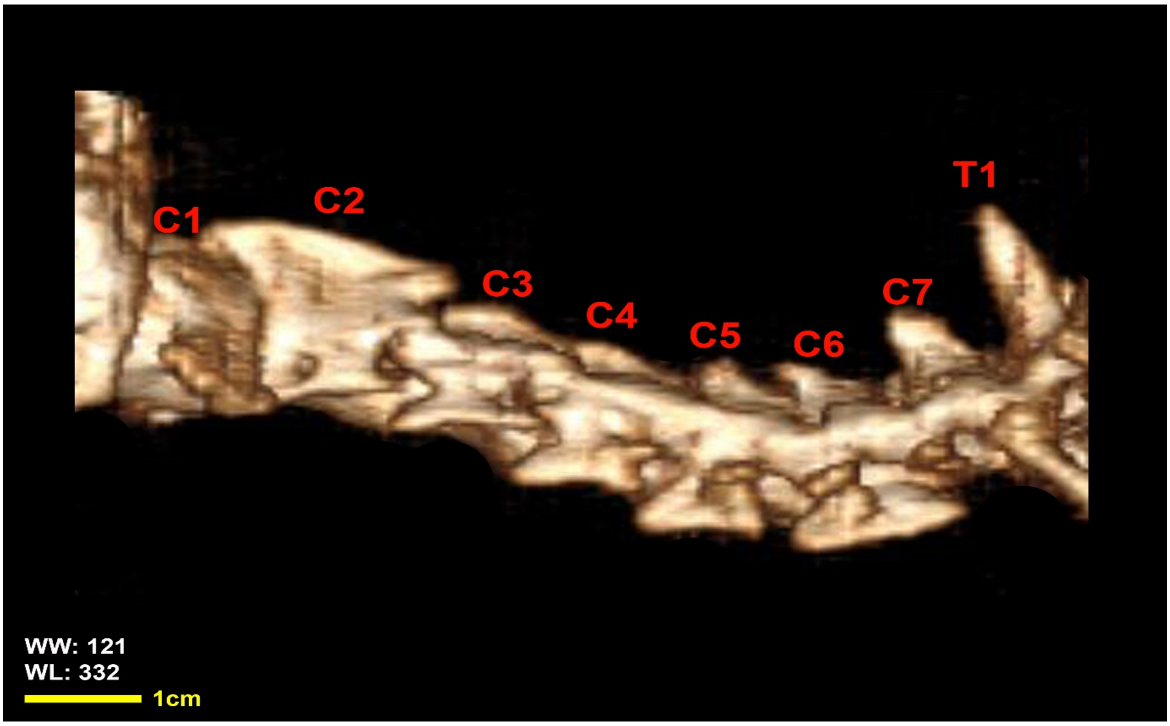

Figure 8. 3D reconstruction image (Lateral view), Osseous-Shaded-vp, cervical vertebrae in rabbit.

Discussion

In this study, the anatomy of cervical vertebrae was evaluated in the adult white New Zealand rabbits using CT scan. Different parts of vertebrae were named and described, and several parameters in the cervical region of vertebral column were measured using the same method. Here we analyze the results of statistical study.

Regarding SPH, there is no significant difference between the second to seventh cervical vertebrae.

Considering TPL, it can be concluded that this parameter is significantly different between the first cervical vertebra and others, and in atlas, TPL size is larger than other cervical vertebrae. Given this parameter, there was a significant difference between atlas and other cervical vertebrae.

Given the meaningful difference between the first cervical vertebra and other cervical vertebrae, it can be concluded that TPA is the least in atlas and is almost horizontal. Moreover, given the significance of difference between the second to fourth cervical vertebrae and atlas, it can be concluded that this parameter is larger in these vertebrae than that in atlas. Additionally, regarding the meaningful difference between the fifth to seventh cervical vertebrae and the second to fourth ones, it can be concluded that this parameter is different between these two groups of vertebrae and is more in the second to fourth than in the fifth to seventh cervical vertebrae.

SCH is equal between the cervical vertebrae. Given the meaningful difference in SCW between the atlas and other cervical vertebrae, it can be concluded that this parameter is different in these vertebrae, and is bigger in atlas than in other cervical vertebrae.

The parameters PDL, PDW, VBL, and EPH were measured in the second to seventh cervical vertebrae. It was observed that there were no significant differences between these cervical vertebrae in terms of these parameters.

Zotti and colleagues in 2009 evaluated the anatomy of neck, thorax, and abdomen of healthy rabbits by CT scan (Zotti, Banzato, Cozzi 2009). The structure and measures of the bones were not reported in their study, but in the present study, we focused on these issues. Van caelenberg *et al.* (2010) evaluated the normal anatomy of head and the soft tissues around it in rabbits. In their study, they did not focus on the features of the atlas while in our study, these features were studied and described. With the aid of CT scans, we precisely studied the rabbit's vertebral column. Hence, this study may act as a good document for diagnosing chronic spinal problems in rabbits. Wilke and colleagues in 1997 evaluated the anatomy of vertebral canal in sheep and compared it with that of human. Similar to our study, they obtained 5 sheep and evaluated and measured almost all parameters of vertebrae (Wilke, 1997). In case of the sheep, the size of VBH decreased from the anterior to the posterior, however no significant change was observed in the rabbit in the current study. In the rabbit, SPH did not change from C2 to C6, and increased significantly in C7, but it was variable in the sheep. TPL in the rabbit did not change from C2 to C6, though it was variable in the sheep. Moreover, TPW in the rabbit did not change from C2 to C4, it increased at C4, and did not change up to C7, though it was the largest in C7 and C5 of the sheep. TPA was not measured in the sheep. SCW in the rabbit was invariable from C2 up to C7. In the sheep, SCW was the greatest in the cervical region. PDW in the rabbit showed an invariable measure from C2 to C7, while it had the smallest size in the sheep between C2 and C6 and increased at C7 (Wilke, 1997).

This study presents a complete and accurate description and morphometric evaluation of cervical vertebrae in rabbits using CT scan. As a remarkable feature of this study, no specimen was killed and anatomical studies were performed using the CT scan technique.

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Conflict of Interest

The authors declared that there is no conflict of interest.

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مجله طب دامی ایران، ۱۳۹۹، دوره ۱۴، شماره ۴، ۴۳۲-۴۲۱

مطالعه سی تی اسکن و ارزیابی مورفومتریک مهره‌های گردنی در خرگوش نیوزیلندی سالم (*Oryctolagus Cuniculus*)

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زمینه مطالعه: امروزه استفاده از خرگوش‌ها در تحقیقات به عنوان حیوان آزمایشگاهی بسیار رایج است ولی اطلاعات کمی دربارۀ آناتومی رادیوگرافی این حیوانات وجود دارد. سی تی اسکن یک روش تشخیصی غیرتهاجمی است که اطلاعات آناتومی جزئی‌تر و دقیق‌تری در اختیار قرار می‌دهد.

هدف: هدف از این مطالعه توصیف کامل و دقیق آناتومی مهره‌های گردنی و ارزیابی مورفومتری این مهره‌ها درخرگوش به وسیله روش سی تی اسکن است.

روش کار: در این مطالعه از دستگاه سی تی اسکن دو آشکارسازه استفاده شده است و چندین پارامتر در تصاویر دو بعدی در ۱۰ خرگوش سالم، بالغ، ماده سفید نیوزیلندی اندازه‌گیری شدند و نتایج حاصل مورد ارزیابی قرار گرفتند.

نتایج: اندازه برخی پارامترها از قبیل VBH, SCH, PDL, PDW, VBL, EPH و EPW در تمامی مهره‌های گردنی تفاوت معنی‌داری نداشتند، ولی اندازه سایر پارامترها از قبیل SPH, TPL, TPW, SPA و TPA دارای تفاوت معنی‌دار بود. در پنجمین مهره گردنی زائده عرضی سه قسمتی بود و دارای سوراخ عرضی بزرگ بود. در ششمین مهره، زائده عرضی شبیه یک صفحه پهن بود.

نتیجه گیری نهایی: مطالعه پارامتر VBH بین مهره‌های دوم تا هفتم گردنی اندازه ثابتی داشته است. پارامتر SPH نیز دارای اندازه ثابت بین مهره‌های دوم تا ششم گردنی است و در محل هفتمین مهره گردنی دارای افزایش اندازه بود و سپس تا اولین مهره سینه‌ای اندازه ثابتی داشته است. این مطالعه شامل توصیف دقیق و کاملی از مهره‌های گردنی و نیز ارزیابی مورفومتری این مهره‌ها در خرگوش به وسیله سی تی اسکن است. شاخص مهم این مطالعه عدم کشته شدن هیچ یک از نمونه‌ها و مطالعه آناتومی و مورفومتری مهره‌های گردنی به وسیله تصویربرداری سی تی اسکن است.

واژه‌های کلیدی: کالبدشناسی، مهره‌های گردنی، سی تی اسکن، مورفومتری، خرگوش

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