Short Paper

Three-dimensional reconstruction of New Zealand rabbit antebrachium by multidetector computed tomography

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(Received 19 Mar 2014; revised version 17 Jan 2015; accepted 18 Feb 2015)

Summary

The aim of this study was to reveal biometric peculiarities of New Zealand white rabbit antebrachium (radius and ulna) by means of three-dimensional (3D) reconstruction of multidetector computed tomography (MDCT) images. Under general anesthesia, the antebrachiums of a total of sixteen rabbits of both sexes were scanned with a general diagnostic MDCT. Biometric measurements of the reconstructed models from high resolution MDCT images were analyzed statistically. Consequently, when biometric measurement values of corresponding bones of antebrachium were compared, it was revealed that there was no statistical significance within both sexes but there were statistically important differences between both sexes in some biometric measurements. It has been suggested that the results from the study can shed light on future studies on the skeletal system and can form a modern point of view to anatomical education.

Key words: Computed tomography, Forearm, Morphometry, Rabbit, Three dimensional reconstruction

Introduction

It is commonly known that rabbits are used in medical researches as experimental animals and most medical instruments are applied to humans after being tried on some animals (Alfidi *et al*., 1975). Recently, computed tomography (CT), which has played a dominant role in diagnosis and evaluation of many diseases, has also been used in veterinary studies (Kara *et al*., 2004). The anatomy-related biometric research via CT makes an important contribution to the determination of breeds (Regedon *et al*., 1991; Onar *et al*., 2002). Multidetector computed tomography (MDCT) is a recent technological advance that allows rapid slicing of images to obtain 2D images, and then getting 3D reconstructed imaging by combining 2D images, thereby allowing a volume data set to be obtained (Hu *et al*., 2000).

There are many macro anatomical studies on thoracic and pelvic limbs of humans and various animals. Some morphometric measurements were made on sheep's ulna and radius using a digital caliper device and the relationships of these values with live weight, shoulder height, age and sex were investigated (Başoğul, 2007; Kutun, 2008; Pazvant and Kahvecioğlu, 2009). Brianza *et al*. (2006) revealed differences between age and sex in big, middle and small bodied dog breeds by measuring their radius and ulna.

It has always been useful to show the location of some anatomical structures on radius and ulna using 3D modeling (Gemmill *et al*., 2006). CT is very useful in planning of treatment for elbow incongruity (House *et al*., 2009). 3D images obtained from CT have been used to form a model in surgical application and detection of antebrachial deformations in dogs (Dismukes *et al*., 2008; Crosse and Worth, 2010). Moreover, CT images are very useful in investigation of developmental disorders caused by trauma and in osteotomy performed during the treatment process in cats (Voss and Lieskovsky, 2007). Oğurtan *et al*. (2002) experimentally studied the effect of ultrasound on the proliferation zone distal to the antebrachium in rabbits. An *et al*. (1996) bilaterally examined the symmetrical properties of femur, tibia and humerus. Pazvant and Kahvecioğlu (2009) obtained the morphometrical values in rabbit long bones in order to show their homotypical variations taking into consideration their sexual difference.

Since there is no study on normal CT anatomy of any limbs of rabbits in previous anatomical descriptions, this present study focused on normal biometric measurements of the rabbit antebrachium by the help of virtual 3D displays created from the MDCT. Finally, the authors revealed various biometric values such as surface area, length, diameter and volume of antebrachium, using 3D reconstructed results of MDCT images of the New Zealand rabbit antebrachium.

Materials and Methods

The antebrachium-related parts of MDCT images were obtained from full screened body of New Zealand rabbits used in a project completed in early 2011 and supported by The Coordination Office of Selçuk

University Scientific Research Projects. Also, it was approved by the ethical committee of the Veterinary Faculty of Selçuk University on 24 June, 2009 (decision number: 2009/056).

Age and weight

In this study, a total of 16 New Zealand rabbits of both sexes (8 males, 8 females) aged 1-1.5 years and weighing between 3 and 3.5 kg were used.

Anesthesia

The rabbits were intravenously anaesthetized with a mixture of 5 mg/kg ketamine-HCl (Ketamidor, RicherPharma AG, Austria) and 20 mg/kg propofol (Propofolamp., Fresenius Kabi, Austria).

MDCT images

MDCT images of animals in prone position were obtained under anesthesia. The parameters of the MDCT (Somatom Sensation 64, Siemens Medical Solutions, Germany) instrument were adjusted as follows: physical detector collimation, 32 × 0.6 mm; final section collimation, 64 × 0.6 mm; section thickness, 0.75 mm; gantry rotation period; 330 ms; kVp, 120; mA, 300; resolution, 512 × 512 pixels; resolution range, 0.92 × 0.92. Dosage parameters and scanning were performed by predicating them on standard protocols and literature (Prokop, 2003; Kalra *et al.*, 2004). Thus, it was tried to obtain radiometric resolution (MONOCHROME2; 16 bit) at the lowest radiation level with optimum image quality. The axial images that were obtained were stocked in DICOM format and then evaluated on a personal computer.

Three-dimensional reconstruction

In the first stage of the automatic segmentation process, the limits of the radius and ulna were determined. The sections out of the limits of each bone were deleted (Fig. 1). Manual correction was performed after controlling again with the naked eye and unneeded places were deleted. Then, reconstruction was carried out with the 3D translator component of the mentioned program by overlapping the images, the limits of which were determined. Three-dimensional images, biometric values such as surface area, length, diameter and volume of antebrachium and modeling of bones were presented (Figs. 2 and 3). All biometric measurements of the antebrachium were carried out by a 3D modeling software (Mimics 13.1, Materialise Group, Belgium).

Measurements

Measurements taken from the radius:

Volume (V): Volume of the radius

Surface area (SA): Surface area of the radius

Body sagittal diameter (BSD): Maximal value obtained in cranio-caudal direction of the body of the radius

Body transversal diameter (BTD): Maximal value obtained in latero-medial direction of the body of the radius

Proximal transversal diameter (PTD): Maximal value of transversal diameter obtained from the widest point of the proximal extremity of the radius

Distal transversal diameter (DTD): Maximal value of transversal diameter obtained from the widest point of the distal extremity of the radius

Body perimeter (BP): Maximal value of circular measure obtained from the body of the radius

Maximal length (ML): Length between the most proximal and distal extremities of the radius

Measurements taken from ulna:

Volume (V): Volume of the ulna

Surface area (SA): Surface area of the ulna

Proximal transversal diameter (PTD): Maximal value obtained in latero-medial direction of the proximal extremity of the ulna

Distal transversal diameter (DTD): Maximal value obtained in latero-medial direction of the distal extremity of the ulna

Body transversal diameter (BTD): Maximal value obtained in latero-medial direction of the body of the ulna

Transversal diameter of tubercle (TDT): Maximal value obtained in latero-medial direction of the olecranon tuberosity

Maximal length (ML): Length between the most proximal and distal extremities of the ulna

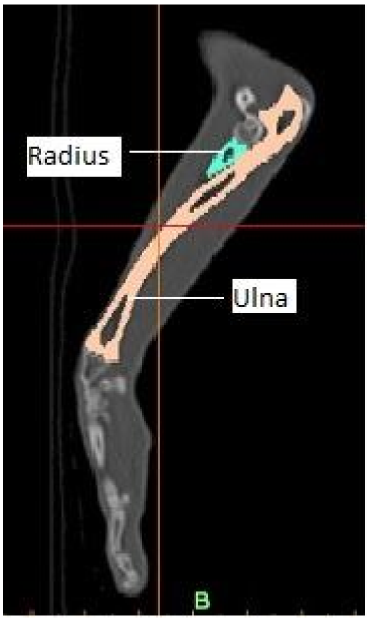

Fig. 1: Limitation of left radius and ulna on coronal section with different colors

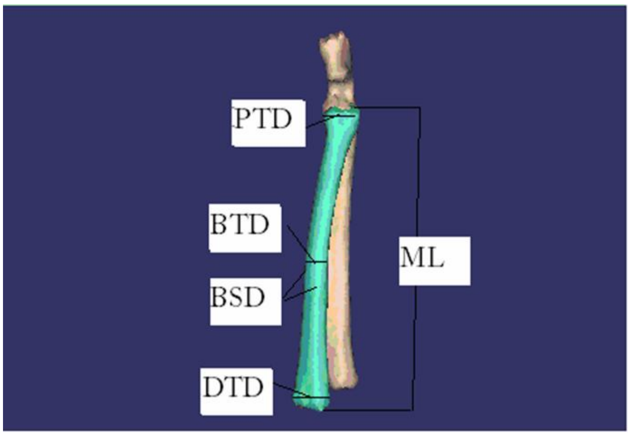

Fig. 2: Points of measurements obtained from radius and ulna (cranio-caudal view)

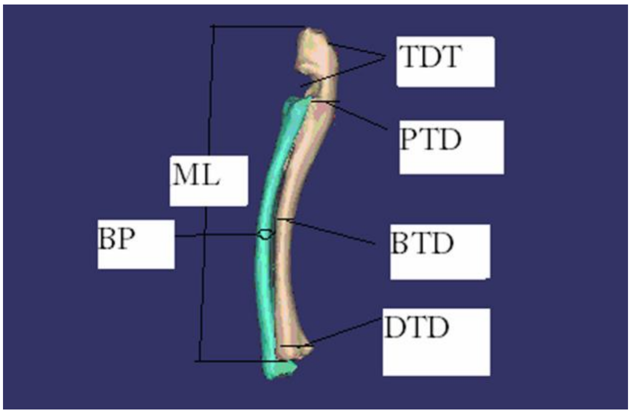

Fig. 3: Points of measurements obtained from radius and ulna (left lateral view)

Statistical analysis

Biometrical measurements of the antebrachium in the right and left sides for males and females were evaluated by paired samples t-test (SPSS 15.0). Data were presented as mean ± standard deviation (SD). $P<0.05$ level was accepted as statistically significant level.

Results

Based on reconstructive results of antebrachium (Fig. 4) of both sides, the biometric measurements obtained were statistically analyzed. Although there was a statistically significant difference shown in the Table 2 between the right and left radius in females with regard to body transversal diameter, no statistical significances ($P<0.05$) were seen between other measurements of the right and left antebrachial bones of the same sexes (Tables 1 and 2). When comparing the right radius-related measurements of both sexes, the surface area, body sagittal diameter, proximal and distal transversal diameter, and body perimeter showed statistically significant ($P<0.05$) differences (Table 3). There were statistical significances ($P<0.05$) between different sexes in terms of surface area, body sagittal diameter, proximal transversal diameter, distal transversal diameter and body perimeter of the left radius (Table 4).

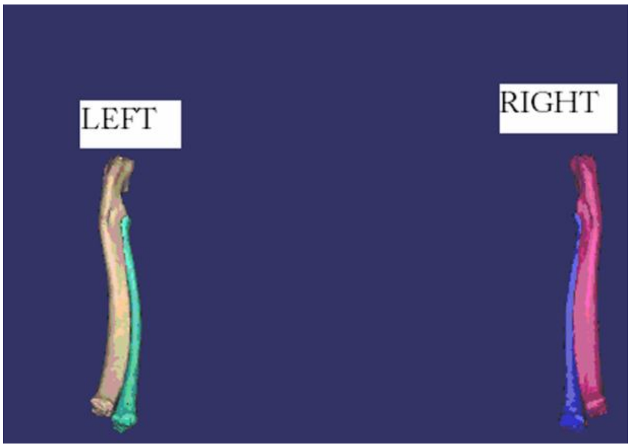

Fig. 4: Medial views of right and left antebrachium

Table 1: Biometric parameters of antebrachium of male New Zealand rabbits obtained from three-dimensional reconstruction of CT images (mean±SD)

Measurements	Radius		Measurements	Ulna	
	Right	Left		Right	Left
V (mm^3)	1241.43 ± 261.86	1262.94 ± 269.34	V (mm^3)	1617.15 ± 234.03	1604.58 ± 252.66
SA (mm^2)	1297.55 ± 175.89	1304.09 ± 175.35	SA (mm^2)	1574.56 ± 173.78	15.76 ± 191.08
BSD (mm)	3.92 ± 0.73	3.86 ± 0.55	PTD (mm)	6.34 ± 1.07	6.6 ± 1.04
BTD (mm)	4.34 ± 0.78	4.91 ± 0.89	DTD (mm)	6.52 ± 0.82	6.09 ± 0.96
PTD (mm)	6.21 ± 0.74	6.8 ± 0.57	BTD (mm)	4.5 ± 0.72	4.6 ± 0.76
DTD (mm)	6.47 ± 0.08	6.44 ± 0.11	TDT (mm)	8.54 ± 1.35	8.81 ± 1.47
BP (mm)	5.39 ± 0.97	4.89 ± 0.60	ML (mm)	71.7 ± 8.29	73.39 ± 8.35
ML (mm)	64.5 ± 10.76	66.65 ± 10.92			

$P>0.05$; there was no statistically significant difference in the same line. V: Volume, SA: Surface area, BSD: Body sagittal diameter, BTD: Body transversal diameter, PTD: Proximal transversal diameter, DTD: Distal transversal diameter, BP: Body perimeter, ML: Maximal length, and TDT: Transversal diameter of tubercle

Table 2: Biometric parameters of antebrachium of female New Zealand rabbits obtained from three-dimensional reconstruction of CT images (mean±SD)

Measurements	Radius		Measurements	Ulna	
	Right	Left		Right	Left
V (mm^3)	1263.01 ± 105.38	1272.57 ± 4.83	V (mm^3)	1271.21 ± 100.74	1279.5 ± 95.14
SA (mm^2)	1053.81 ± 31.42	1072.59 ± 40.36	SA (mm^2)	1055.97 ± 27.83	1067.16 ± 35.5
BSD (mm)	3.13 ± 0.62	3.15 ± 0.64	PTD (mm)	5.58 ± 0.93	5.67 ± 0.94
BTD (mm)	3.96 ± 0.61*	4.78 ± 0.63*	DTD (mm)	4.4 ± 0.8	4.19 ± 0.8
PTD (mm)	5.34 ± 0.67	5.67 ± 0.64	BTD (mm)	4.37 ± 0.74	3.68 ± 0.62
DTD (mm)	5.03 ± 0.35	4.95 ± 0.36	TDT (mm)	7.63 ± 0.69	7.74 ± 0.69
BP (mm)	3.48 ± 1.03	3.62 ± 1.01	ML (mm)	76.91 ± 3.25	77.99 ± 3.53
ML (mm)	66.29 ± 4.23	67.37 ± 4.58			

* In the same line are statistically significant ($P<0.05$). V: Volume, SA: Surface area, BSD: Body sagittal diameter, BTD: Body transversal diameter, PTD: Proximal transversal diameter, DTD: Distal transversal diameter, BP: Body perimeter, ML: Maximal length, and TDT: Transversal diameter of tubercle

Table 3: Biometric parameters of right antebrachium of male and female New Zealand rabbits obtained from three-dimensional reconstruction of CT images (mean±SD)

Measurements	Radius		Measurements	Ulna	
	Male	Female		Male	Female
V (mm^3)	1241.43 ± 261.86	1263.01 ± 105.38	V (mm^3)	1617.15 ± 234.03*	1271.21 ± 100.74*
SA (mm^2)	1297.55 ± 175.89*	1053.81 ± 31.42*	SA (mm^2)	1574.56 ± 173.78*	1055.97 ± 27.83*
BSD (mm)	3.92 ± 0.73*	3.13 ± 0.62*	PTD (mm)	6.34 ± 1.07	5.58 ± 0.93
BTD (mm)	4.34 ± 0.78	3.96 ± 0.61	DTD (mm)	6.52 ± 0.82*	4.4 ± 0.8*
PTD (mm)	6.21 ± 0.74*	5.34 ± 0.67*	BTD (mm)	4.5 ± 0.72	4.37 ± 0.74
DTD (mm)	6.47 ± 0.08*	5.03 ± 0.35*	TDT (mm)	8.54 ± 1.35	7.63 ± 0.69
BP (mm)	5.39 ± 0.97*	3.48 ± 1.03*	ML (mm)	71.7 ± 8.29	76.91 ± 3.25
ML (mm)	64.5 ± 10.76	66.29 ± 4.23			

* In the same line are statistically significant ($P<0.05$). V: Volume, SA: Surface area, BSD: Body sagittal diameter, BTD: Body transversal diameter, PTD: Proximal transversal diameter, DTD: Distal transversal diameter, BP: Body perimeter, ML: Maximal length, and TDT: Transversal diameter of tubercle

Table 4: Biometric parameters of left antebrachium of male and female New Zealand rabbits obtained from three-dimensional reconstruction of CT images (mean±SD)

Measurements	Radius		Measurements	Ulna	
	Male	Female		Male	Female
V (mm^3)	1262.94 ± 269.34	1272.57 ± 94.83	V (mm^3)	1604.58 ± 252.66*	1279.5 ± 95.14*
SA (mm^2)	1304.09 ± 175.35*	1072.59 ± 40.36*	SA (mm^2)	1576.1 ± 191.08*	1067.16 ± 35.5*
BSD (mm)	3.86 ± 0.55*	3.15 ± 0.64*	PTD (mm)	6.6 ± 1.04	5.67 ± 0.94
BTD (mm)	4.91 ± 0.89	4.78 ± 0.63	DTD (mm)	6.09 ± 0.96*	4.19 ± 0.8*
PTD (mm)	6.8 ± 0.57*	5.67 ± 0.64*	BTD (mm)	4.6 ± 0.76*	3.68 ± 0.62*
DTD (mm)	6.44 ± 0.11*	4.95 ± 0.36*	TDT (mm)	8.81 ± 1.47	7.74 ± 0.69
BP (mm)	4.89 ± 0.6*	3.62 ± 1.01*	ML (mm)	73.39 ± 8.35	77.99 ± 3.53
ML (mm)	66.65 ± 10.92	67.37 ± 4.58			

* In the same line are statistically significant ($P<0.05$). V: Volume, SA: Surface area, BSD: Body sagittal diameter, BTD: Body transversal diameter, PTD: Proximal transversal diameter, DTD: Distal transversal diameter, BP: Body perimeter, ML: Maximal length, and TDT: Transversal diameter of tubercle

The volume, surface area and distal transversal diameter of the right ulna showed statistically significant differences between females and males (Table 3). Similarly, regarding the mentioned measurements including the body transversal diameter, the left ulna between different sexes also exhibited a statistically significant difference (Table 4).

Discussion

Authors (An *et al.*, 1996; Pazvant and Kahvecioğlu, 2009) pointed out that the right and left osteometric measurements of long bones of thoracic and pelvic limbs belonging to New Zealand rabbits of the same sexes had no statistical significance. Similarly, this study showed that there was no statistical significance between the right and left values of the antebrachial bones in both sexes.

When researchers (Brianza *et al.*, 2006) investigated tomography images of some long bones in different body sized dogs of different sexes, they concluded that neither sex nor age had a statistically significant effect on section diameters of bones. Pazvant and Kahvecioğlu (2009) also stated that there were no statistically important differences between the biometric measurements of corresponding bones of different sexes. However, statistical significances were revealed between corresponding bones of different sexes (Tables 3 and 4).

The fact that the radius and ulna were statistically insignificant in New Zealand rabbits in both females and males in the right and left sides is in agreement with the findings that Pazvant and Kahvecioğlu (2013) identified regarding the radius and ulna of guinea pigs. However, the fact that they did not find a significant difference between the sexes is in contrast with the findings of our study. On the other hand, the fact that they found a statistically significant difference between the sexes in the ulna bears similarity to the findings of our study.

Stereological methods are used to obtain 3D quantitative information by examining 2D sections and to reveal microscopic structures (Gundersen *et al.*, 1988). In stereological methods, sections are taken using tissue slicing instruments and sections thicknesses may be as large as 3-4 mm. Random selections are made from these sections and other stereological procedures are applied and surface area and volume calculations are made (Selcuk and Bahar, 2014). Stereological studies can also be conducted via MR images and here sections thicknesses vary between 1 and 3 cm (Taşmektepligil, 2009). Interslice distance of 2D computerized tomography images used in 3D reconstructive studies is quite low (0.5 mm) and therefore the number of sections is quite high. All of these sections are used indiscriminately in 3D modeling. Measurements such as volume, surface area, length and angle can be automatically calculated via a model that is created using a computer program. The reliability and validity of these models were revealed when measurements taken on the model and cadavers were overlapped (Kim *et al.*, 2012). Moreover, while the results of stereological studies can be reached only after a long application procedure, this time period is quite short in 3D reconstructive studies. The most crucial feature of 3D reconstructive studies is that animals continue their lives after their tomographic images are taken, which is important ethically.

Consequently, when biometric measurements of antebrachium in New Zealand rabbits were compared, it was shown that there was no statistical significance within both sexes, but there were statistically important differences between both sexes. It has been suggested that this study can shed light on the future studies on skeletal system and can form a modern point of view to anatomical education.

Acknowledgement

This study abstract was submitted as an oral presentation at the VII. National Veterinary Anatomy Congress in Antalya, Turkey on 27-29 October 2011. The abstract was published in the proceedings book.

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