A study on evaluation of 3D virtual rabbit kidney models by multidetector computed tomography images

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Abstract

Objectives: This study was performed to reveal biometric peculiarities of New Zealand rabbit kidneys by means of three-dimensional (3D) reconstruction of multidetector computed tomography (MDCT) images.

Methods: Under general anaesthesia, the kidneys of eight rabbits of both sexes were scanned by high resolution imaging using a general diagnostic MDCT. The thoracic and lumbar vertebrae of the rabbit were used as reference structure to locate exact position of the kidneys in the rabbit body. Finally, landmarks of the kidneys were identified and labelled in the MDCT images and then 3D models were formed to analyse the locations, dimensions and volumes of the kidneys with respect to the vertebral column in transparently modelled body.

Results: The left and right kidney volumes are 9153.3 mm^3 and 9761 mm^3 respectively. The right kidney is approximately 9% longer, 22% wider and 27% thicker than the left kidney. The left kidney is 16% flatter than the right one.

Conclusion: The authors have proposed that the 3D reconstructed results of the MDCT images can contribute to the anatomical education and clinical applications.

Key words: CT imaging; three-dimensional reconstruction; morphometry; kidney; rabbit

Introduction

Rabbits are used in human and veterinary medicine as experimental animals. Most medical instruments are also applied to humans after being tested generally on some animals.[1] Technical achievements and the strict application of accurate anatomical knowledge to surgical and clinical practices have added a new dimension to the diagnosis and the surgical or medical treatments of some diseases. It has been already known that computed tomography (CT) currently plays a dominant role in diagnosis and evaluation of many human diseases and human anatomic structure. Recent papers have also described the use of the CT in veterinary medicine.[2,3] Before any tool can become an effective diagnostic modality, normal species - specific data must be characterized. Publication of clinically relevant CT anatomy is basic to effective utilization of this modality in veterinary medicine.[4] The CT anatomy can be used not only in diagnostic procedures but also in many biometric researches, which constitutes an immense contribution to the evaluation of breeds.[5,6]

Previous anatomical descriptions on the rabbit kidneys were rather superficial.[7,8] Moreover, as there is no study on normal CT anatomy of the rabbit, this study

was focused on normal biometric measurement of the rabbit kidneys by the help of pseudo-3D displays created from the multidetector computed tomography (MDCT) images. The MDCT is a recent technologic advance that allows rapid volume cover speed combined with thin-slice images to create a volume data set suitable for workstation analysis in two-dimensional axial display, multiplanar reformation, or three-dimensional reconstructed imaging. The data obtained from the MDCT are sent to a computer to reconstruct all of the individual "snapshots" into a cross-sectional image (slice) of the internal organs and tissues for each complete rotation of the source of x rays. Pseudo-3D displays are also created from a stack of 2D images of a large number of these parallel planes as snapshots.[9]

Authors have suggested that for following studies reduced slice thickness is the most significant factor to obtain more detailed multiple three-dimensional reconstructive images, and that the results from this study can also shed light on surgical and anatomical investigations related to rabbit kidney.

Materials and Methods

A total of eight adult healthy New Zealand Rabbits of both sexes aged 1.5-2 years and weighing between 3.5 and 4 kg were used. Animals were intravenously anaesthetized with 5 mg/kg of ketamine-HCl (Ketamidor™ Richer Pharma AG, Wels, Austria) and 20 mg/kg propofol (Propofol™ amp., Fresenius Kabi, Austria). Under anaesthesia, in a prone position the animal body was scanned by high resolution imaging using a general diagnostic MDCT. The MDCT was performed with a 64-section CT system (Somatom Sensation 64; Siemens Medical Solutions, Forchheim, Germany). Scanning along the axial axis was performed by using the following parameters: physical detector collimation, 32 x 0.6 mm; resulting section collimation, 64 x 0.6 mm; section thickness, 0.75 mm (increment, 0.7 mm); gantry rotation time, 330 msec; kVp, 120; mA, 300; spatial resolution, 512 x 512 pixels with pixel spacing, 0.92 x 0.92 and radiometric resolution MONOCHROME2 which gives 16 bit gray level. Dose and scanning parameters have been performed by radiologists in Meram School of

Medicine, University of Selçuk, Konya, Turkey, on the basis of the standardized protocol which considers the documented scanning practices and the recent studies[10,11] to generate optimum image quality while maintaining individual radiation exposure at the lowest level. The axial images obtained were then stored in DICOM format to transfer to a personal computer in which the 3D modelling software (3D-DOCTOR for Windows, Ay Tasarım Ltd., Ankara, Turkey, http://www.aytasarim.com) was set up. This study considered the manually corrected automated segmentation for 3D reconstruction of images as in the literature.[12] The points that have been improperly positioned after automatic boundary segmentation were edited manually throughout an interactive boundary editing routine; therefore this segmentation is called as semi-automatic segmentation. Manual editing process takes 3 to 4 minutes per image. Semi-automatic segmentation was done by determining the kidney boundaries automatically first, then the points which were not correctly positioned on the kidney boundaries were edited point by point with a computer mouse. After manual editing was rechecked visually, all the corrected boundaries of the kidney surfaces were stacked and overlaid to reconstruct the 3D model of bones by 3D rendering component of the software.

The average measures describing rabbit kidneys by the 3D virtual models

Based on the 2D images of axial sections from the CT, renal average measurements of both sexes regarding locations, dimensions and volumes and illustrations were recorded and reconstructed in the 3D for the average rabbit body. Considering thoracic and lumbar vertebrae used as reference model, whose 3D reconstructed images were obtained by only automatic segmentation procedures on the 2D CT images, some space coordinates of both kidneys were also measured.

It has been proposed that both biometric perspectives and the 3D reconstruction technique performed in this work add a new dimension to the future studies on reconstructive studies.

Results

Some slides among all slices of the rabbit body and related to the kidneys were used for the construction of the 3D virtual kidney models. In **Figure 1,** top part shows two CT slices located almost at the centre of each kidney's volumetric space. Measurements edited on the images are referred to the volumetric centre position of each kidney with respect to the corresponding centre of the vertebral canal appearing in the same slice. So, radial distances between these two volumetric centres are 33 mm and 45 mm according to right and left kidneys respectively. It can also be seen from the **Figure 1** that both kidney centres are located vertically at 15 mm down with respect to their corresponding vertebral centres. It means that there is no offset between the kidney centres with respect to the corresponding vertebrae. Focusing onto the bottom part of **Figure 1,** it can be seen that radial distance is 75 mm between the kidney centres.

Contrary to that there is no vertical offset between the kidney centres, there is an offset at the extent of 40.2 mm along the backbone direction and the right kidney comes first than the left kidney according to the rabbit's head location.

Volume data of both kidneys were obtained from the CT images through the constructed 3D models. The left and right kidney volumes are therefore 9153.3 mm^3 and 9761 mm^3 respectively and the right kidney is about 7% bigger than the left one. **Figure 2** depicts side and front view of the 3D virtual right and left kidneys with length, width and thickness measurements, considering the extremist points of the right and left kidneys in the 3D models. As it is seen from the figure, the right kidney is approximately 9% longer, 22% wider and 27% thicker than the left kidney with respect to the dimensions of about 39.9 mm, 26 mm and 25.1 mm and of about 36.5 mm, 21.4 mm and 19.8 mm for the length, width and thickness of the right and left kidneys respectively. Flatness is 3% and 19% for the right and left kidneys, respectively. So, the left kidney is 16% flatter than the right one. The angle between the plane passing through both kidney centres and the transversal plane is foundas 28°.19.

Discussion

In this study, as the semi-automatic segmentation procedures on the 2D CT images make some incorrect label assignment, the manual editing has been also has been also added to the image processing procedure to show nearly absolute 3D images and geometrical measurements of the rabbit kidneys. Therefore, it can be said that the 3D reconstructed images and findings from this study reflect accurately the true anatomical properties of the kidneys. Based on the 3D geometrical kidney, plastic rabbit kidney models of real dimension can also be created. Moreover, as long as the medical imaging and photogrammetry reasonably approximate each other, it may
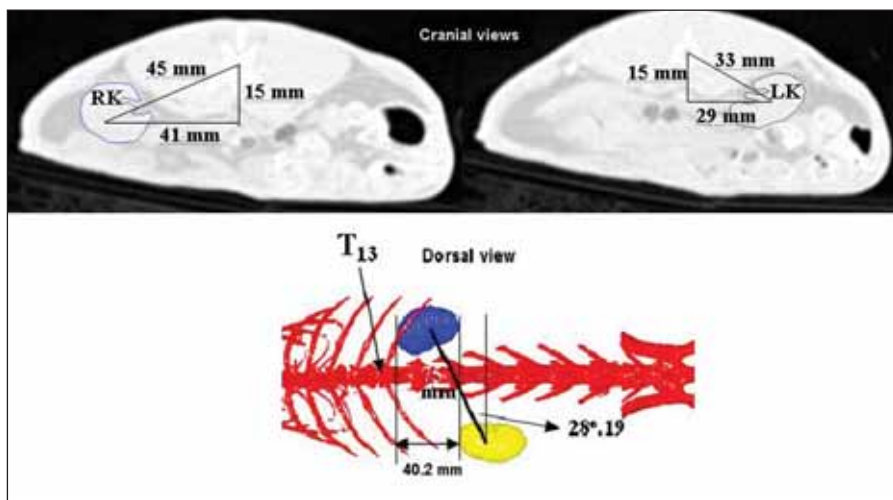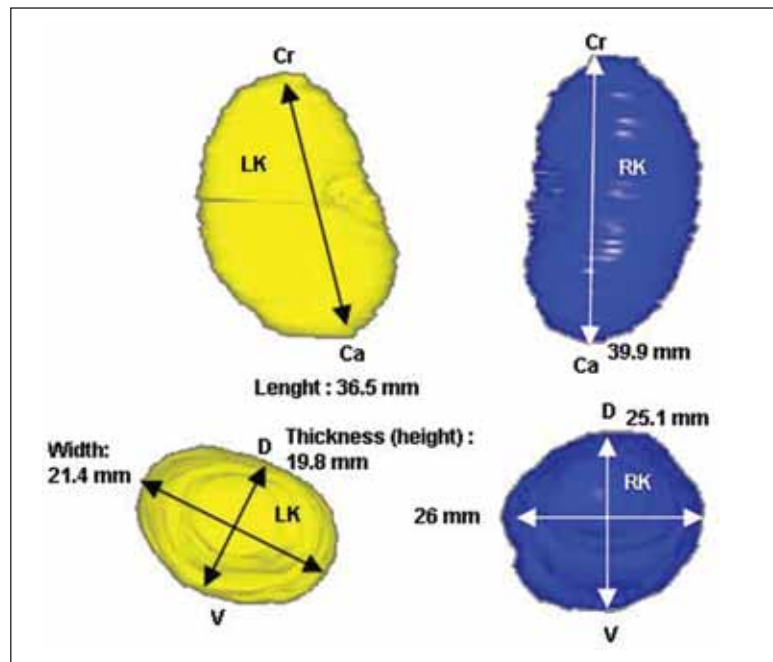

Figure 1. Measurements describing the location of rabbit kidneys with respect to one another. RK: right kidney; LK: left kidney.

Figure 2. Dimensions of right and left rabbit kidneys. **Length:** cranial to caudal; **Thickness:** dorsal to ventral; **Width:** lateral to medial. **Ca:** caudal; **Cr:** cranial; **D:** dorsal; **LK:** left kidney; **RK:** right kidney; **V:** ventral.

be possible to create new approaches for diagnostic and therapeutic procedures of the kidney related pathological disorders. It is true that this study have limitations depending on the manual editing, which introduces operator dependency and time consumption, and the technique may not be suitable for routine evaluation of the kidneys. However, in this study our main purpose has already been to provide basic morphometric information regarding the rabbit kidneys.

The authors showed that 3D modelling software (3D-DOCTOR) used in this study can be useful for obtaining various biometric measurements from reconstructed kidney models as the other softwares which were included in human reconstructive studies.[13,14] Nevertheless, some renal size-related-measurements obtained from computerized tomography with 3D reconstruction may have not absolute accuracy enough to take into consideration in renal transplantations.[15]

In conclusion, the present study is the first to analyse the location, size and volume of rabbit kidneys in situ by 3D reconstruction of the 2D MDCT images. When considered point of medical view, the exact 3D reconstruction of a disease-suspected or evident anomalous region and its real time examination is very important.

Finally, parameters related to volume, shape of an anatomical structure including its relationships to critical regions can be determined thus being made an appropriate choice for treatment. The authors also suggest that this work adds a modern dimension to anatomical education.

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