Computed tomography and cross-sectional anatomy of the head in healthy rabbits

Annemie I. Van Caelenberg, DVM; Lieve M. De Rycke, PhD; Katleen Hermans, PhD; Leen Verhaert, DVM; Henri J. van Bree, PhD; Ingrid M. Gielen, PhD

Objective—To obtain a detailed anatomic description of the rabbit head by means of computed tomography (CT).

Animals—6 clinically normal Dendermonde White rabbits weighing 3 kg and raised for human consumption and 1 Netherland dwarf rabbit.

Procedures—The commercially raised rabbits were slaughtered in a slaughterhouse, flayed, and decapitated. The dwarf rabbit was euthanatized. Two hours later, each rabbit head was positioned with the ventral side on the CT table to obtain transverse and sagittal, 1-mm-thick slices. Dorsal images were obtained by placing each head perpendicular to the table. Immediately after the CT examination, 3 heads were frozen in an ice cube at −14°C until solid and then sectioned at 4-mm-thick intervals by use of an electric band saw. Slab sections were immediately cleaned, photographed, and compared with corresponding CT images. Anatomic sections were examined, and identified anatomic structures were matched with structures on corresponding CT images.

Results—The bone-window CT images yielded good anatomic detail of the dentition and the bony structures of rabbit skulls. The soft tissue structures that could be determined were not better identifiable on the soft tissue–window CT images than on the bone-window images.

Conclusions and Clinical Relevance—CT images of the heads of healthy rabbits yielded detailed information on the skull and some surrounding soft tissue structures. Results of this study could be used as a guide for evaluation of CT images of rabbits with various cranial and dental disorders. (Am J Vet Res 2010;71:293–303)

Because rabbits are commonly kept as pets, veterinary practitioners need to be aware of the specific health problems of this species. Continuous growth and eruption of their teeth makes rabbits susceptible to dental abnormalities.1–3 The most common dental problems are cheek teeth (premolar and molar) overgrowth, incisor overgrowth, facial abscess, periodontal disease, and diseases of the nasolacrimal duct.3–6 Diagnosis of such problems is often difficult. Besides intraoral inspection and collection of a thorough clinical history, radiographic or CT examination of the head may be necessary to identify deformations of the teeth and dental arcades.3,4,7–9

Use of CT in diagnosing dental abnormalities in exotic animals is growing,3,5,8,10,11 and an increasing number of published clinical reports10,12,13 involve dental CT. However, publications regarding CT anatomy of anatomically normal heads in these species are rare. To accurately interpret CT scans of the rabbit head, a thorough knowledge of the anatomic features of clinically normal heads is necessary. To our knowledge, only 1 publication14 includes a description of the cross-sectional anatomy of the rabbit head. In another textbook;15 only a few CT scans of the head of a healthy rabbit are described, whereas a third publication16 includes a brief description of chinchilla dentition on CT images. A recently published overview8 concerning the application of CT for the diagnosis of dental disease in rabbits, guinea pigs, and chinchillas provides some detailed CT images of an anatomically normal rabbit skull. Some anatomic CT images of the normal rabbit head are provided in another report17 by the same author. To our knowledge, a detailed study of gross anatomic sections of the rabbit head to identify structures visible on CT scans has not been conducted. The purpose of the study reported here was to provide a comprehensive atlas of the skull and the surrounding soft tissue structures in clinically normal rabbits.
rabbits by use of anatomic sections and corresponding CT images.

Materials and Methods

Animals—Six commercially raised, clinically normal adult Dendermonde White rabbits weighing 2.5 to 3.5 kg and 1 adult Netherland dwarf rabbit weighing 0.7 kg were used. None of the rabbits had a history of dental disease, and no abnormalities were detected during physical examinations. Three radiographic images of the entire head were obtained for each rabbit: dorsoventral, left lateral, and rostrocaudal views. No radiographic abnormalities were found on any image. The 6 commercially raised rabbits were humanely slaughtered in an officially recognized slaughterhouse in accordance with Belgian regulations on animal welfare, flayed, and decapitated. The dwarf rabbit was anesthetized by use of medetomidine hydrochloride (0.2 mg/kg, IM) and ketamine (10 mg/kg, IM), euthanatized in the clinic for reasons unrelated to dental condition, and decapitated. For euthanasia, a combination of etubramide, mebentoinoidide, and tetracaine (0.5 mL/kg, IV) was administered.

CT—Two hours after decapitation, a CT examination was performed on each rabbit head by use of a spiral, single-slice CT scanner.4 Settings for the CT image technique were 140 kV and 160 mA. Image matrix was 512 × 512. For the transverse images, the field of view was 10 cm, and for the sagittal and dorsal images, the field of view was 18 cm for all 7 rabbits. Bone algorithm and pitch was 1. Each rabbit head was positioned with the ventral side on the CT table, and a preliminary lateral and a dorsoventral CT-generated image were made. Transverse, 1-mm-thick, contiguous, single slices were obtained from the nares to the occipital condyles, perpendicular to the hard palate. Subsequently, each head was rotated 90° on the CT table, and 1-mm-thick sagittal slices were obtained. Dorsal images were obtained by positioning the heads perpendicular to the table with the nose tipped upward.

Each image was reviewed in standard DICOM format5 by use of 2 window settings: bone (window width, 3,700 HU; window level, 1,400 HU) and soft tissue (window width, 270 HU; window level, 100 HU). Data for all 7 rabbits were retrieved and analyzed by use of a workstation with viewing software.1

Comparison of CT and anatomic images—At the end of CT examination, 3 heads of the commercially raised rabbits were frozen in an ice cube at −14°C until solid. One frozen head was placed on the movable table of an electric band saw;8 and serial transverse sections were cut approximately 4 mm apart, beginning at the nares and ending at the occipital condyles. From the second head, 4-mm-thick sagittal slices were cut. The third head was cut in 4-mm-thick dorsal slices, parallel to the soft palate. All slices were gently cleansed of debris with cold tap water and light brushing. The 2 surfaces of each section were photographed immediately (ie, before thawing).

Photographs were examined, and identifiable anatomic structures were labeled with the aid of an anatomic atlas.14 Nomenclature used for designating all structures was chosen in accordance with official anatomic terminology.18 For each anatomic slice, a corresponding CT image was chosen on the basis of similar appearance. Identified structures were subsequently located on CT images. Afterward, the list of identified structures was evaluated on the CT images of the other 4 rabbit heads.

Results

Nine representative transverse combinations of images extending from the nares to the occipital condyles were selected in the first rabbit, 3 sagittal-matched pairs of images were chosen in the second rabbit, and 3 dorsal combinations were chosen in the third rabbit.

The 9 transverse selected levels of the rabbit head, at which anatomic sections and their corresponding CT images were obtained, were indicated on a lateral survey view; the 3 sagittal and dorsal levels were respectively indicated on a lateral and a dorsoventral survey view (Figure 1). Identifiable anatomic structures in heads of commercially raised adult rabbits were labeled on cadaver sections and corresponding CT images (Figures 2–4). Images from CT scans of the dwarf rabbit’s head were compared with those of

![Figure 1](image)

Figure 1—Computed tomographic views of the skull of a clinically normal adult rabbit indicating the level and angle at which CT images and corresponding anatomic skull sections were obtained and compared in a study of the anatomy of the rabbit head. A—Lateral CT scan indicating levels of transverse (A through I) and dorsal (J through L) images. B—Dorsoventral CT scan indicating levels of sagittal (M through O) images.
Figure 2—Transverse anatomic sections (left) and corresponding bone-window CT scans (right) of the skull of a clinically normal adult rabbit. Images were obtained at levels A through I as defined in Figure 1. P2 = Second premolar. P3 = Third premolar. P4 = Fourth premolar.
Figure 2—Transverse anatomic sections (left) and corresponding bone-window CT scans (right) of the skull of a clinically normal adult rabbit. Images were obtained at levels A through I as defined in Figure 1.
the commercially raised rabbits at levels B, E, H, K, N, and L (Figures 5–7).

On the anatomic sections of rabbit heads, all dental structures and numerous bony and soft tissue structures could be identified. From the dentition, the first and second incisors as well as all maxillary and mandibular cheek teeth were distinct, particularly on the sagittal and dorsal slices. On the transverse anatomic sections, some cheek teeth happened to be in the unsectioned interval. Various skull bones were visible such as the incisive bone, nasal bone, ethmoid bone, maxilla, palatine bone, sphenoid bone, frontal bone, parietal bone, interparietal bone, zygomatic bone, temporal bone with tympanic bulla, occipital bone with foramen
magnum and occipital condyles, mandible, hyoid bone, and atlas.

At the level of the nasal cavities, it was possible to identify the ethmoturbinates, the nasal meati, the dorsal and ventral conchae, and the nasal septum. The dorsal and ventral portions of the maxillary sinus and the vomeronasal organ were also visible. Adjacent soft tissue structures such as some neck muscles, the eyes, lacrimal canal, zygomatic and sublingual gland, nasopharynx, soft palate, oropharynx, several mastication muscles (masseter, pterygoid, and digastric muscles), tongue muscles (mylohyoid, geniohyoid, genioglossal, hyoglossal, and styloglossal muscles), buccal mucosa with buccinator muscle, lip, epiglottis, larynx, trachea, esophagus, mandibular lymph nodes, external acoustic orifice, and auricle of the ear were quite distinct. Parts of the brain could easily be distinguished, including the olfactory bulb, optic tract, cerebral cortex piriform lobe, hippocampus, corpus callosum, thalamus, interthalamic adhesion, hypothysis, lateral and third ventricles, rostral and caudal collicles, cerebral peduncles, pons, trigeminal nerve, cerebellar hemispheres, medulla oblongata, and spinal medulla.

On the bone-window CT scans, it was possible to identify all teeth, particularly on the sagittal and dorsal images. All skull bones and parts of the nasal cavities identified on the anatomic slices could be seen on the CT scans. The recess of the maxillary sinus and the

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Figure 3—Dorsal anatomic sections (left) and corresponding bone-window CT scans (right) of the skull of a clinically normal adult rabbit. Images were obtained at levels J through L as defined in Figure 1. M1 = First molar. M2 = Second molar. M3 = Third molar. P1 = First premolar. See Figure 1 for remainder of key.
vomeronasal organ were distinct. Additionally, the frontal sinus was visible on 2 transverse CT images (levels E and F).

On the soft tissue–window CT scans, several soft tissue structures could be located such as the eyes, lacrimal canal, zygomatic gland, nasopharynx, buccal mucosa, esophagus, and external acoustic orifice. It was possible to locate some parts of the brain such as the olfactory bulb, cerebral cortex and peduncles, piriform lobe,pons, cerebellum, and spinal medulla. The mastication muscles (masseter, pterygoid, and digastric muscles) and tongue muscles (mylohyoid, geniohyoid, geniglossal, hyoglossal, and styloglossal muscles) could not be seen; only their supposed position was evident on the CT scans. Dentition could not be evaluated on the soft tissue–window CT scans.

For the other 3 commercially raised rabbits, all structures mentioned for the first 3 rabbits could be seen on the corresponding CT images. In 3 rabbits, the bones of the larynx were more distinct on the transverse scans, compared with the appearance on the scans of the other rabbits (level F).

On the transverse bone-window CT scans (levels B, E, and H) of the dwarf rabbit head, the frontal sinus was

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Figure 4—Sagittal anatomic sections (left) and bone-window CT scans (right) of the skull of a clinically normal adult rabbit. Images were obtained at levels M through O as defined in Figure 1. See Figures 1 and 2 for remainder of key.
Figure 5—Comparison of transverse bone-window CT scans of the skull of a dwarf rabbit (left) and soft tissue-window scans of skulls of commercially raised rabbits (right) at levels B, E, and H as defined in Figure 1.
not visible. Compared with the CT scans of the commercially raised rabbit, the ventral nasal concha appeared to be less delineated. On the sagittal CT scans of the dwarf rabbit head (level N), the frontal sinus was not identified; on the dorsal CT images, it was impossible to determine the fifth mandibular cheek tooth (third molar).

Discussion

Radiographic complexity attributable to superimposition of the facial bones and teeth can be overcome by use of CT images in animals. Other advantages of CT versus conventional radiography are the variation in grayscale formats, which can enhance detection of specific structures (such as soft tissues) and reconstructions in multiple anatomic planes.

In veterinary medicine, CT scanners calibrated for human sizes are commonly used. This may result in rather unsharp CT images when scanned objects are small, such as with rabbit or rodent skulls. The small size of exotic animals will result in smaller images that
contain a smaller number of pixels, resulting in a lower-resolution image. The disadvantage of the lower resolution of CT images versus radiographs is compensated for by the ability to view slices in various planes. Human pediatric CT scanners or micro-CT scanners provide linear reformating, compared with conventional CT scanners. However, because of limited access to micro-CT equipment in veterinary practice and for financial reasons, micro-CT has been primarily used for research in veterinary medicine.13

Spiral CT provides excellent detail of the fine bony structures of the skull and adjacent soft tissues in small exotic animals.19,20 However, the resolution of CT images is superior when a single-slice spiral scanner is used instead of a multislice spiral CT unit.21 Spiral CT is an outstanding modality for the complete evaluation of dental arcades in animals with continuously growing teeth (eg, chinchillas, rabbits, or guinea pigs), resulting in the detection of changes before they become clinically or radiographically apparent.5,9,17,12 Whereas radiographic interpretation by an experienced examiner typically reveals only approximately 85% of the pathological change present, CT will yield more accurate information.15,22

The present investigation was carried out to characterize the anatomic features of the rabbit dentition and the surrounding structures of the head by means of a spiral single-slice CT scanner. To maximize the image resolution, the smallest field of view and the maximum matrix size allowed by the scanner were used. Also, the thickness of the slices (1 mm) was minimized to reduce the partial volume artifact that yields image blur. Computed tomographic images acquired through the transverse, sagittal, and dorsal planes provided detailed anatomic information. Most investigators prefer the use of transverse CT images for diagnosing dental pathological change.5,12 The transverse plane is indeed most appropriate for use in determining the length and direction of the cheek teeth roots. This plane also provides information about the occlusion plane of the cheek teeth and the presence of dental spikes. Furthermore, delineation of the orbita and nasal cavity can be inspected. Dorsal images can be obtained by positioning the rabbit in dorsal recumbency, with the nose tipped upward. They are useful for inspection of the dentition, particularly the possible elongation and direction of the tooth roots. In addition, the orbita, nasal cavity, and sinuses can be delineated. Use of the sagittal plane has not been described by other investigators because it is impossible to obtain sagittal images in live rabbits. However, after completion of a transverse CT examination, postprocessing by means of multiplanar reconstruction is possible to achieve sagittal views.8

To obtain reconstructions of excellent quality and high detail, it is important to reduce the slice thickness as much as possible, particularly with single-slice CT scans. The newest multislice CT scanners permit submillimeter collimation slice width and can provide an isotropic data set that allows not only optimal plane resolution but also an identical spatial resolution of multiplanar reformatting in all directions.8 Computed tomographic images of rabbit heads in the sagittal plane may be useful in defining the direction and possible elongation of incisor crowns and cheek teeth roots. Besides the delineation of the nasal cavity and orbita, the mandibular cortex can also be inspected. In the present study, it was possible to obtain sagittal CT images because only the heads of the rabbits needed to be positioned in the CT scanner. These sagittal slices can be used as a reference for identification of structures on sagittal reconstructed images of live rabbits.

Because dwarf rabbits are commonly evaluated in veterinary practice, CT images of a dwarf rabbit were compared with corresponding CT images of the larger rabbits. Except for the inability to define the frontal sinus and the tiny fifth mandibular cheek tooth, no clinically important differences were evident between the paired sets of images.

On the soft tissue–window CT images of the rabbit heads in our study, some of the surrounding soft tissue structures could be identified. However, compared with the bone-window CT images, these soft tissue structures were not remarkably better delineated. Only the supposed position of the structures could be indicated by aid of their position on the corresponding anatomic images. Magnetic resonance imaging provides soft tissue detail superior to that of CT, but the identification of the surrounding soft tissue structures was not the primary goal of the present study. The main purpose was to provide an atlas of CT images of the rabbit head with emphasis on dentition.

References
12. Crossley DA, Jackson A, Yates J, et al. Use of computed tomo-