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This Issue:
Dentistry of Exotic Companion Mammals

Vittorio Capello, DVM
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Guest Editors

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Clinical Technique: Application of Computed Tomography for Diagnosis of Dental Disease in the Rabbit, Guinea Pig, and Chinchilla

Vittorio Capello, DVM,
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Abstract

Computed tomography (CT) is a well-recognized diagnostic tool in human and traditional companion animal medicine, and is beginning to find application in exotic companion mammals as well. In particular, CT is useful for evaluation of patients with dental disease, and aids diagnosis, determination of a more accurate prognosis, and planning of treatment. Although axial slices provide the most useful information, new reconstruction software allows images to be converted to virtual 3-dimensional forms, providing yet another imaging tool for the practitioner.

Key words: **computed tomography; dentistry; rabbit; guinea pig; chinchilla**

Diagnostic imaging is one critical component of the complete evaluation of dental disease and related complications in rabbit and selected rodent species. Radiographs help evaluate structures not visible during the physical examination and inspection of the oral cavity. However, standard radiography has a number of limitations, including an inability to demonstrate areas of bone loss and osteomyelitis because it is difficult to impossible to isolate single portions of the skull without superimposition of other bony and soft tissue structures. Computed tomography (CT) of the head is an outstanding diagnostic tool that overcomes some of the limitations of standard radiology. The advent of newer CT scanners and the availability of user friendly post-capture image manipulation software make this modality extremely useful and a practical adjunct to standard radiology.

Computed Tomography

CT is a radiologic technique to obtain multiple, parallel cross-sectional image slices of the tissues of the patient. The name "tomography" comes from the Greek "tomos," which means "to cut," and "gramma," which means "letter" (e.g., image).

Multiple x-ray exposures are made as an x-ray tube within a gantry rotates around the patient and it moves along the gantry on a couch (Fig 1). The final image is generated by a computer.

The concept of "slice" imaging originated from the need to overcome superimposition of imaging that is intrinsic to conventional radiography. In

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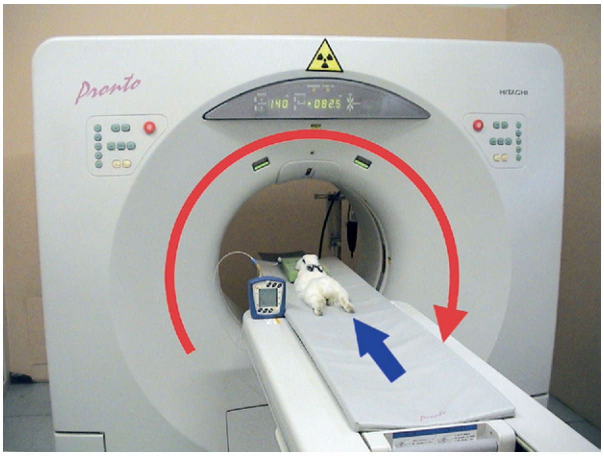

Figure 1. Rabbit under general anesthesia with injectable drugs positioned on the couch for CT scanning. Spiral CT scanners collect slices through combined movements of the rotating x-ray tube and movement of the patient through the tunnel. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

actuality, the main difference between CT and traditional radiography is that in the latter, all tissues in the area of interest are superimposed over a single plane.

CT was developed by Godfrey Hounsfield and A. J. Cormack in the early 1970s, and the first scanner was used to image the human head in 1972. Second-, third-, and fourth-generation whole-body scanners were developed in the late 1970s and 1980s, modestly improving scan speed and image resolution. In 1987, the first continuously rotating scanner or spiral scanner was produced. This dramatically reduced scan time because image data could be continuously acquired compared with the start-stop motion of single-slice scanners. Newer CT scans elaborate images via the standardized, internationally recognized DICOM format, which allows a greater number of visual options and virtual 3-dimensional (3D) renderings.

Basic Operation of a CT Scanner

A narrow cone-shaped x-ray beam is used for CT acquisition and traverses a very small volume or slice of tissue as it moves through an arc of 360°. An array of electronic x-ray detectors records the multiple exposures generated by the x-ray tube. Because the x-ray beam is narrow, slice thickness is generally 1 to 5 mm, and even less than 1 mm with

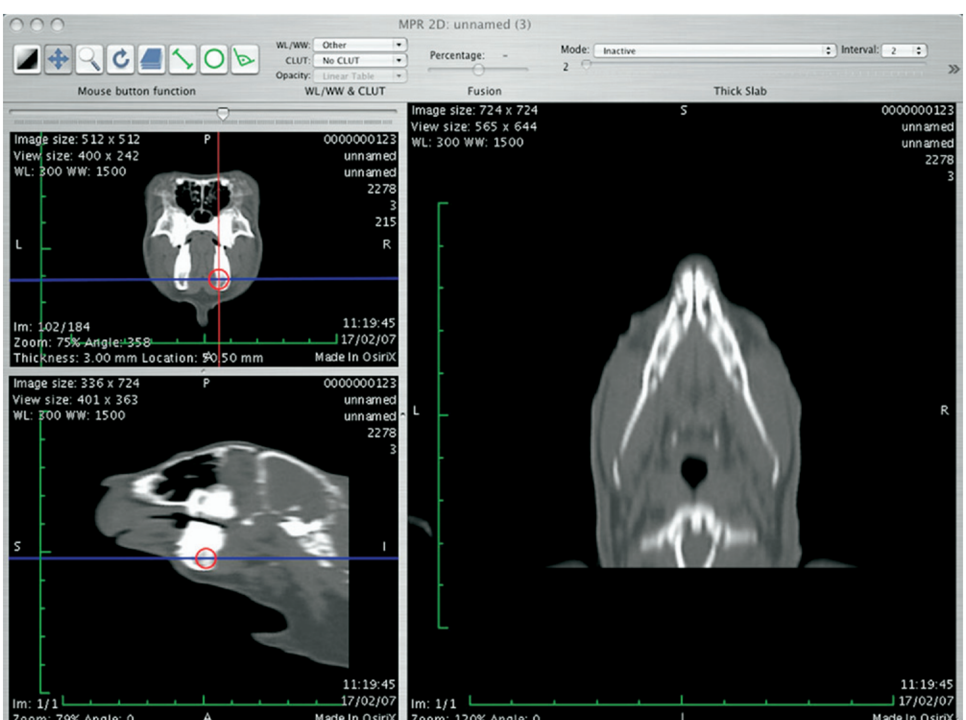

Figure 2. A 2-dimensional multiplanar reformation (MPR) presents the 3 basic planes (axial, lateral, coronal) all together. By moving the "target" (the small red circle), the section planes are selected and automatically reconstructed. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

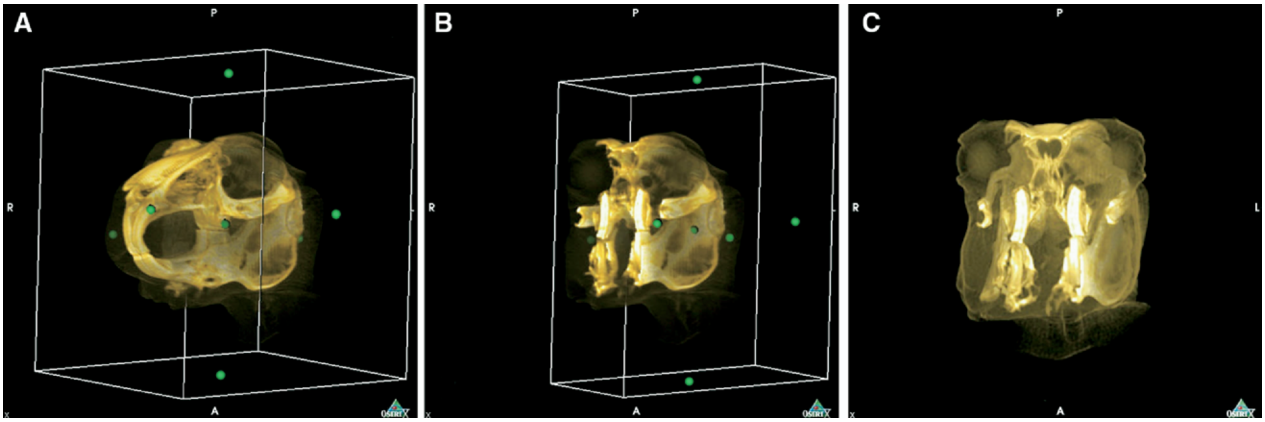

Figure 3. The 3D volume rendering format is used to visualize an entire block of tissue or body part, such as the head. To make volume rendering more representative of actual organ structure, the tissues that are not of interest are deleted, enhancing the tissues of interest. High-speed computers allow the image to be rotated in any direction. Volume rendering is most effective when only a few tissues or structures are represented. Presently, it is the most useful reconstructive method in CT; however, it should only be used in conjunction with transverse gray scale images because it is only a representation of the actual data set (*A*). Movement of a single side effectively crops away that aspect of the 3D image, allowing visualization of inner anatomical structures (*B*). A volume rendering cropped at the level of the cheek teeth shows the axial section of a severe osteomyelitic area of the right mandible (*C*). Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

new spiral scanners. X-rays exiting the animal excite the detectors, producing an electrical signal that is proportional to x-ray intensity. A computer processes, digitizes, and stores the electrical signal. The ability of tissues within the image slice to attenuate incident x-rays determines the intensity of the x-rays reaching the detectors.

The 3D tissue slice is divided into tiny blocks called voxels. Voxels have length, width, and depth; the latter is determined by the thickness of the tissue slice. Through a complex reconstruction process, the computer analyzes the mean attenuation of each voxel and assigns a CT number. Water is the reference standard and is assigned a CT number of 0; cortical bone is +1000 and air is –1000. Fluids, soft tissues, and fat have intermediate CT numbers. All the CT numbers are converted to various shades of gray on the final image. The window of CT numbers representing the gray scale can be adjusted to maximize the tissue of interest. Choice of window settings affects image contrast. For instance, narrow windows provide

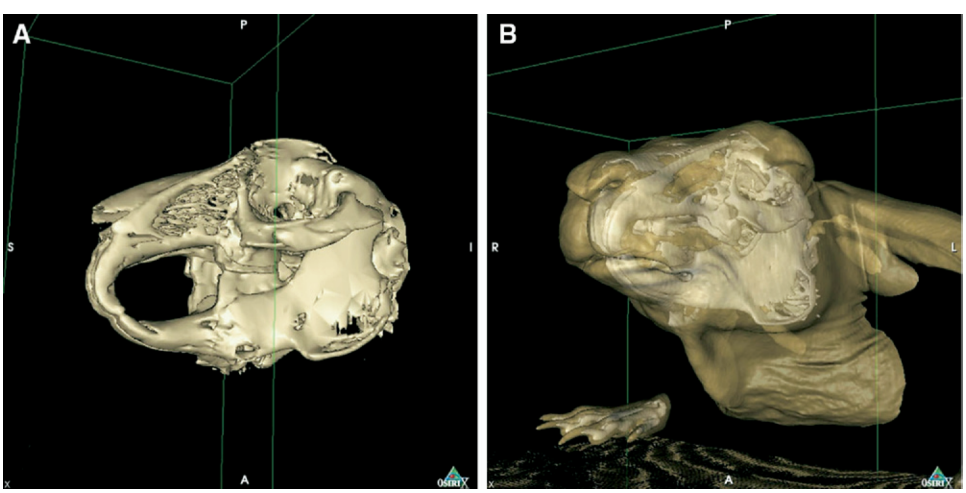

Figure 4. 3D shaded surface display (SSD) permits virtual reconstruction of the actual surface of tissues, allowing the analysis of complex structures. The primary use of SSD is for hard tissues, like bones and teeth (*A*). The 3D surface rendering can be rotated in any position in space, aiding in diagnosis and treatment planning. A double-surface reconstruction (soft tissues/hard tissues) is also possible (*B*). This can be useful for the analysis of relationship between different organs and tissues. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

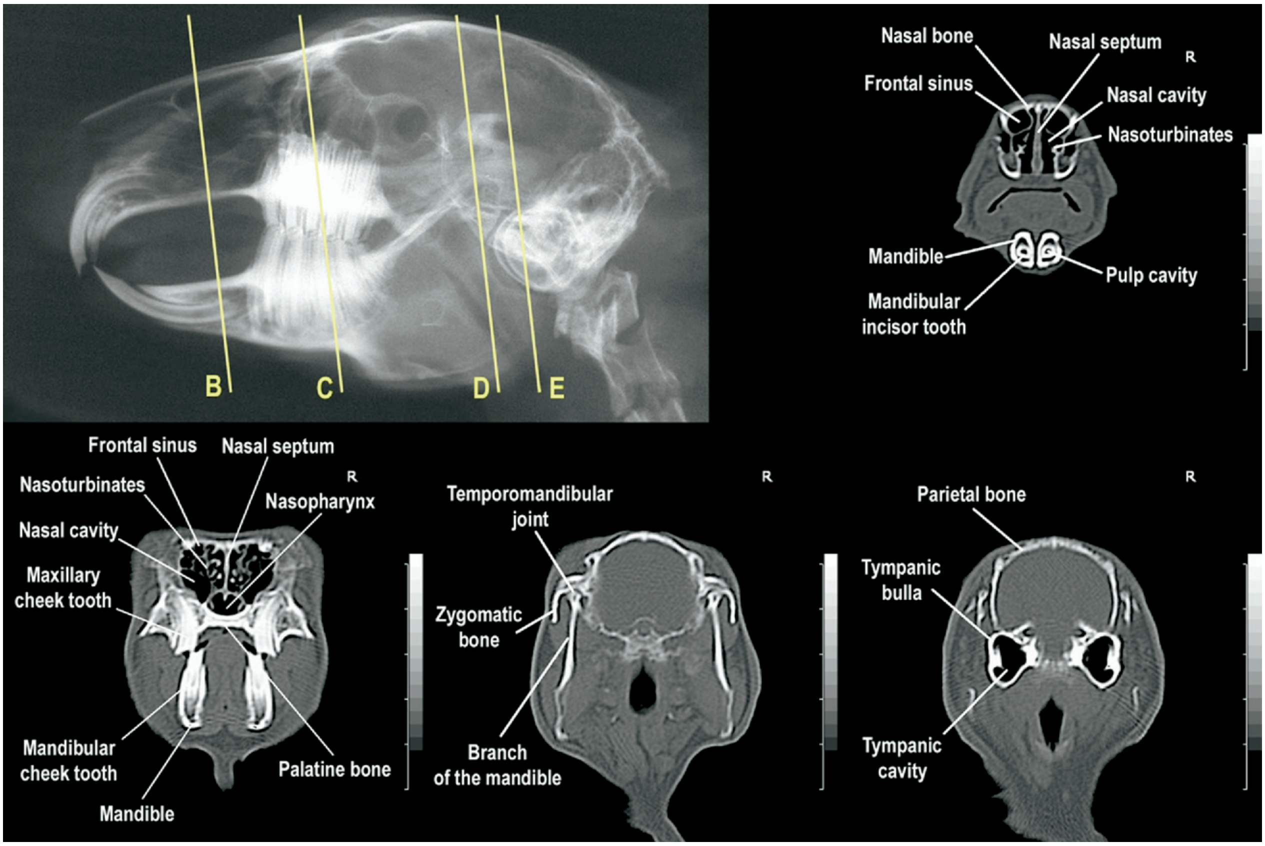

Figure 5. CT of the normal skull of a 1.8-kg rabbit; bone window. Scanning parameters: scan speed, 1 sec; mA, 125; kilovolt (peak), 120; slice thickness, 3 mm; reconstruction index, 0.5 mm; WL, 300; WW, 1500; image size (matrix), 512 × 512 pixels. The scout view demonstrating the scanning angles has been adapted from a radiograph of the normal skull for demonstration purposes. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

high contrast and better differentiation of soft tissues because gray scale is spread over a relative few CT numbers. Narrow window settings are commonly used for abdominal imaging. On the other hand, wide window settings reduce the contrast because available gray shades are spread over a wide range of CT numbers. Wide window settings are preferred for imaging bone because soft tissue structures lack contrast and are suppressed, whereas bony structures are well visualized.

Data are almost always acquired in the transverse plane (axial slices) but can be reformatted by the computer and also displayed in sagittal, coronal, and lateral planes. This capability is called multiplanar reformation (MPR) and has been exploited by the advent of spiral CT (Fig 2). It must be remembered that although the actual image slice has 3 dimensions (x, y, and z), printed images and images seen on a monitor have only 2 dimensions. However, with interactive monitor viewing, the actual image volume can be viewed as a series of slices by moving the computer mouse. This maneuver will give the interpreter a 3D sense of spatial orientation of the various structures in the image volume. Dedicated imaging software programs allow various reconstruction techniques, including volume rendering (VR) techniques and shaded-surface displays (SSD) (Figs 3 and 4). So-called VR formats show the entire image volume with certain CT numbers suppressed (e.g., only numbers below or above a threshold are chosen). For instance, only a map of the pulmonary vasculature can be displayed, with the remainder of the lung suppressed. When the image volume or maximum/minimum intensity projection is presented in this fashion, there may be a perception of depth and 3D effect, but the actual image is 2-dimensional.

SSDs present a contoured surface map of the entire image volume. The volume can be rotated on the monitor to allow the observer to visualize any surface. SSDs have limited usefulness because deep structures are masked, but they are helpful for evaluating abnormalities of the bones of the skull (e.g., osteomyelitis and skull fractures). Although reforma-

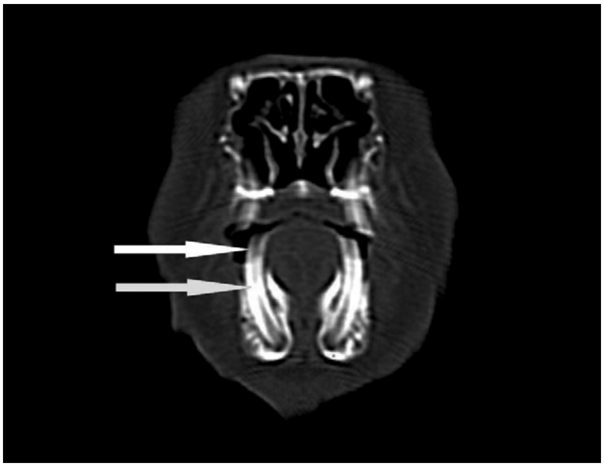

Figure 6. Standard scanning plane angles have been established for some canine breeds, but there are no standards for exotic animals. Scanning plane angles for the skull images of the rabbit, guinea pig, and chinchilla shown in this article are perpendicular to the palatine bone. However, further studies may suggest additional advantageous angles, in particular for the study of the mandible and cheek teeth. Note that this particular scanning angle in these species produces slices that are not parallel to the axis of cheek teeth, therefore each slice, depending on thickness, may intersect more than one tooth, showing two mandibular cheek teeth in the same slice. This artifact is known as “traslato piano” (“translated plane”). Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission

tions give the interpreter a different perspective, transverse slices still provide the most information and are always interpreted before any type volume rendering is performed on the image data.

Computed Tomography Post-capture Imaging Software

Software for manipulation of DICOM images to volume and surface reconstruction format is readily available. A quick search on the internet revealed a number of products with varying operating system requirements and pricing for purchase. OsiriX is an online freeware currently available to Macintosh users. All of the reconstructed images presented in this article have been created with this software. These products require practice, and most manufacturers provide customer support.

Application of Computed Tomography for Exotic Companion Mammals

The use of spiral CT for exotic mammals is a new discipline, and few references are available. Most recent improvements in CT scans include reduction of scan time and improved image resolution, factors that make such scans feasible and useful even for small exotic patients (Table 1).

Imaging exotic patients is a challenge because of their small size. The consequence of smaller patient size is production of a small image containing a smaller number of pixels which is, by nature, lower resolution. Because spiral scanners offer very thin slices (even less than 1 mm) and large image matrices (512 × 512 pixels), resolution is superior to that obtained with most single-slice scanners (Figs 5-10). High-resolution CT images can be magnified 1.5× to 2.0× with computer software, allowing better detection of subtle anatomic changes. Despite the fact that the resolution of analog or digital convential radiology is superior, viewing slices of the patient in sagittal and coronal planes as well as the standard axial plane offers tremendous advantages. Contrast resolution (e.g., the ability to see various soft tissues) is also superior with spiral CT scanners. By adjusting image contrast (window level and width) to the anatomic structure of interest (e.g., soft tissue, bone, lung), the problem of low, soft to hard tissue ratio

Table 1. Suggestions for clinicians interested in obtaining CT for their patients

1. Contact a university or referral center willing to consider performing CT. Be certain the equipment is a newer-generation spiral CT that produces images in the DICOM format.
2. Acquire appropriate software to view DICOM images.
3. Discuss handling of anesthesia for the procedure. Many referral centers are not comfortable with anesthesia for exotic companion mammals and may require the referring clinicians to handle this aspect.
4. During the scanning procedure, limit positioning equipment to foam blocks only. Do not allow the technician to use tape, gauze, or a positioning rack. These items can interfere with the scanning process, and they will likely be rendered as part of the reconstructed surface display and interfere with interpretation. Standardize positioning as described or develop a personal positioning technique based on scans of normal animals with the specific equipment in question.

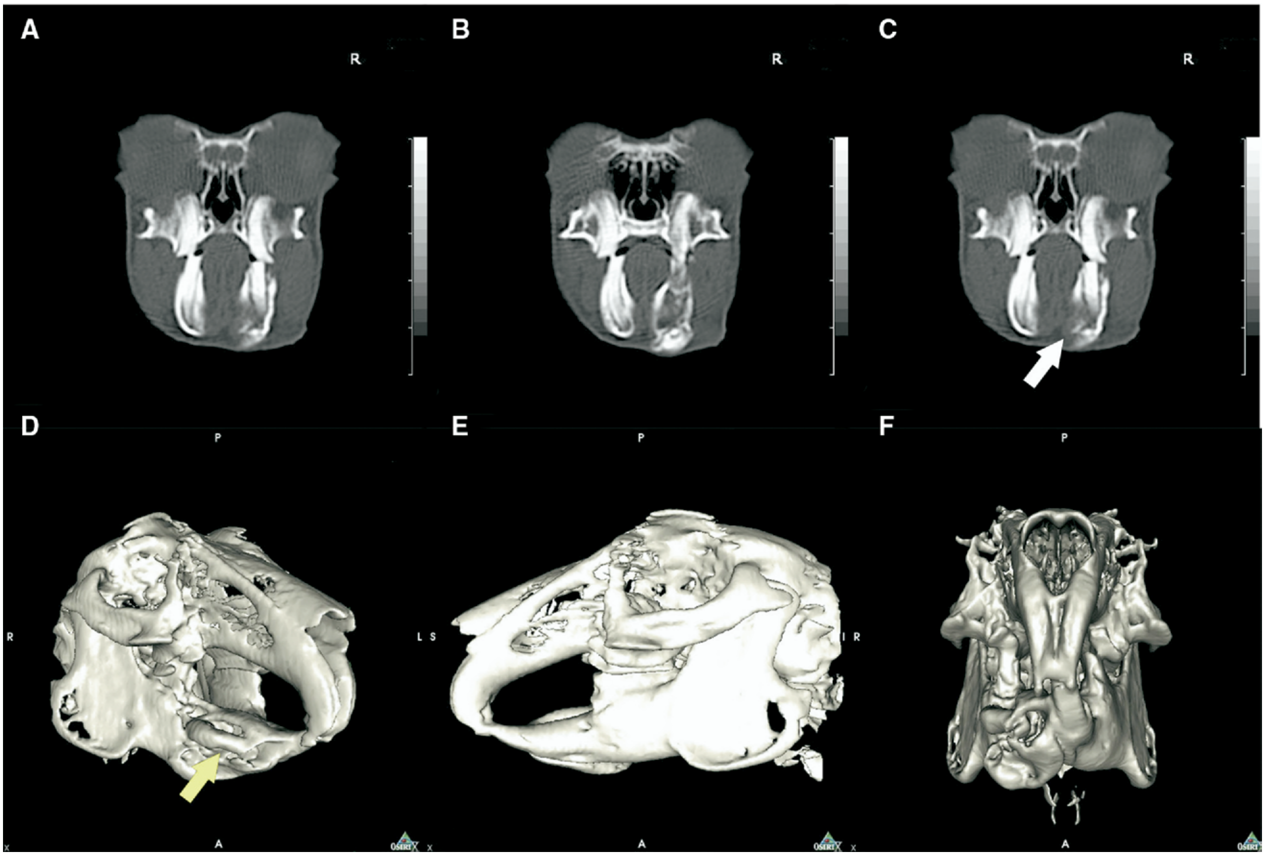

Figure 7. Osteomyelitis of the right mandible after periapical infection of the omolateral incisor tooth; bone window. Scanning parameters: scan speed, 1 sec; mA, 125; kilovolt (peak), 120; slice thickness, 3 mm; reconstruction index, 0.5 mm; WL, 300; WW, 1500; image size (matrix), 512 × 512 pixels. Comparison between the normal and the diseased body of the mandible is visible (*A, B, C*). A medial fistula is present at the level of right mandibular check tooth 3 (*c*, *arrow*). SSD of the skull in the same patient (*D, E, F*). The osteomyelitic body of the mandible is visible (D) as well as the apex and fragmented reserve crown of the right mandibular incisor tooth (*arrow*). The normal left mandible is shown in (E). The comparison between the normal and the diseased mandible is also visible from the rostral view (*F*). Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

in small mammals can be minimized. Even with size limitations, however, very good images can be obtained with the latest generation of CT machines.

Sedation or anesthesia are essential for proper positioning for CT and for reducing breathing artifact, especially in smaller mammals with a higher respiratory rate, despite the fact that the scanning time is brief. The patient is commonly positioned in ventral recumbency, with the head elevated slightly and kept horizontal. The endotracheal tube will not create a superimposition as in conventional radiographs. Nevertheless, the connection with the anesthetic circuit can hamper perfect symmetric positioning. Even though the scanning time is short, simple inhalant induction of anesthesia is not an effective option because the mask cannot be held in place during scanning, which increases the chance the patient will revive and move. The authors prefer an injectable protocol to allow adequate time for positioning, scanning, and verification of the CT images.

Before scanning, a scout view is collected in both dorsoventral and lateral projection. Scout projections are standard x-ray images that are used to ensure accurate positioning of the patient, select the anatomic region to be scanned, and can later be used as a reference for location of individual slices. The dorsoventral projection is useful for evaluating bilateral symmetry, and the lateral projection is useful for the selection of the angle of the scan plane. A provisional transverse scan through the tympanic bullae can also be made to check for proper position of the head if desired.

The software of certain CT machines includes an option for “reconstruction index”. When raw data is elaborated, this option virtually reduces the thickness of native slices (e.g.: from one 2 mm slice to two

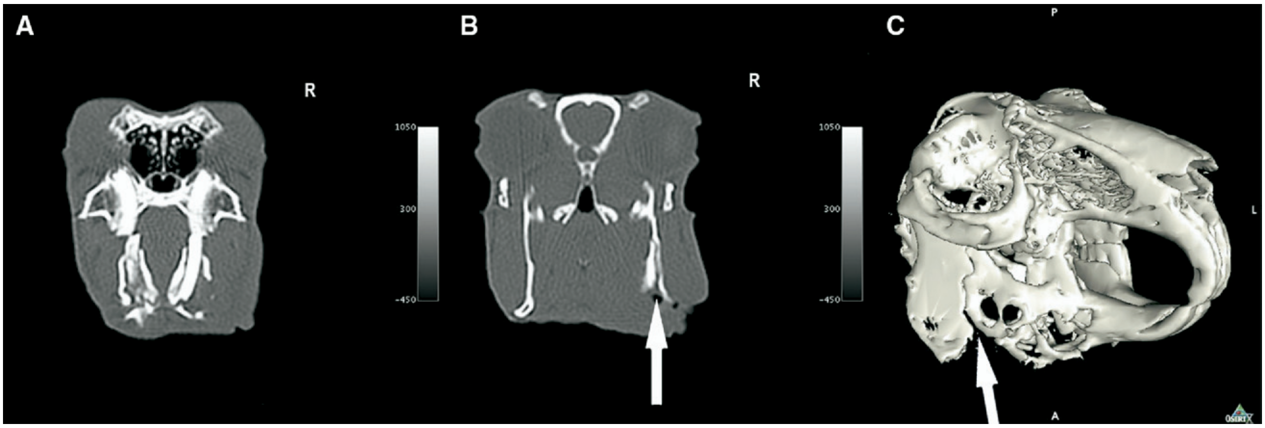

Figure 8. Case of bilateral mandibular periapical infection and osteomyelitis in a 2-year-old 1.5-kg rabbit; bone window. Bilateral mandibular periapical infection and osteomyelitis is visible in (*A*). A radiodense line suggestive of a fracture of the branch of the mandible (*arrow*) is visible in (*B*). SSD (*C*) shows bone loss extending along the right mandibular body to the ramus. A vertical fracture of the ramus is also visible (*arrow*). Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

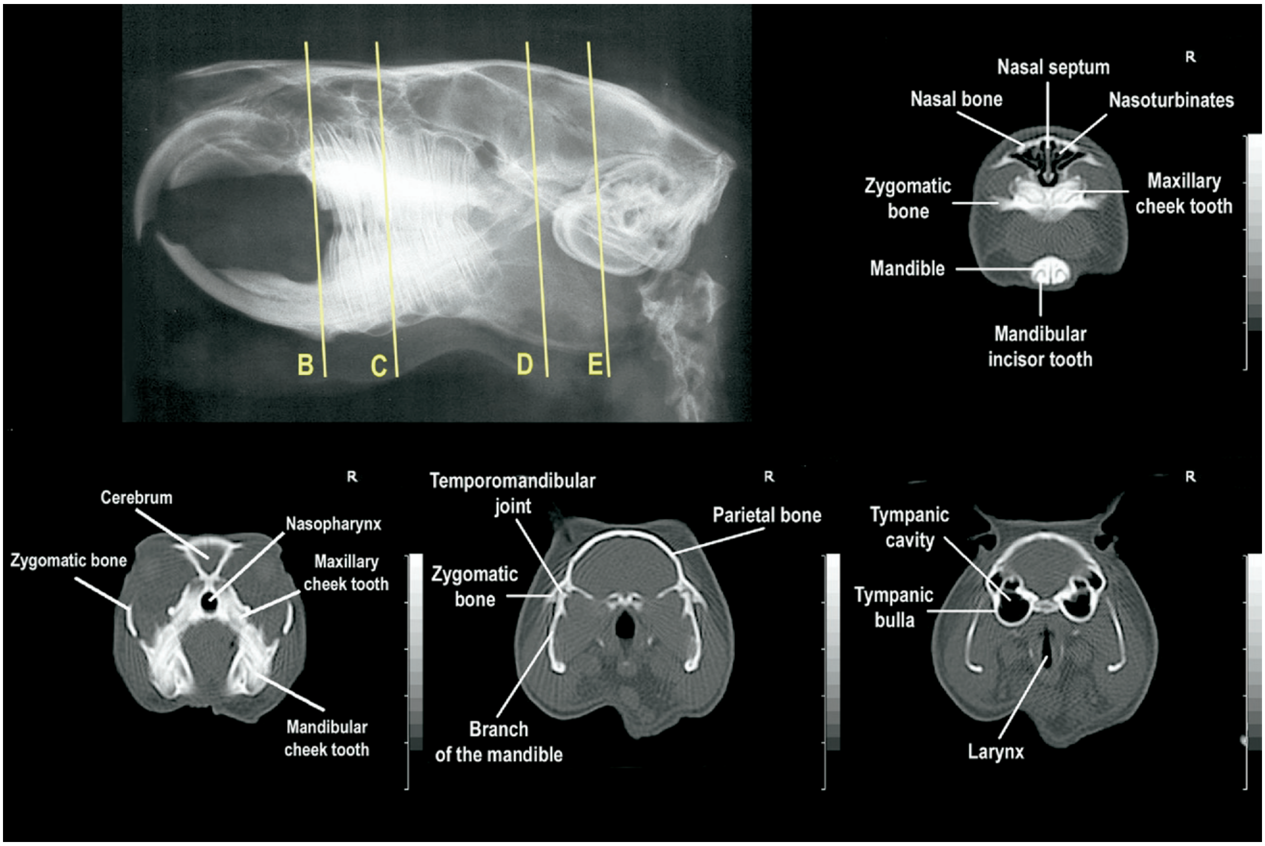

Figure 9. CT of the normal skull of a 1.1-kg guinea pig; bone window. Scanning parameters: scan speed, 1 sec; mA, 125; kilovolt (peak), 120; slice thickness, 3 mm; reconstruction index, 0.5 mm; WL, 300; WW, 1500; image size (matrix), 512 × 512 pixels. The scout view demonstrating the scanning angles has been adapted from a radiograph of the normal skull for demonstration purposes. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

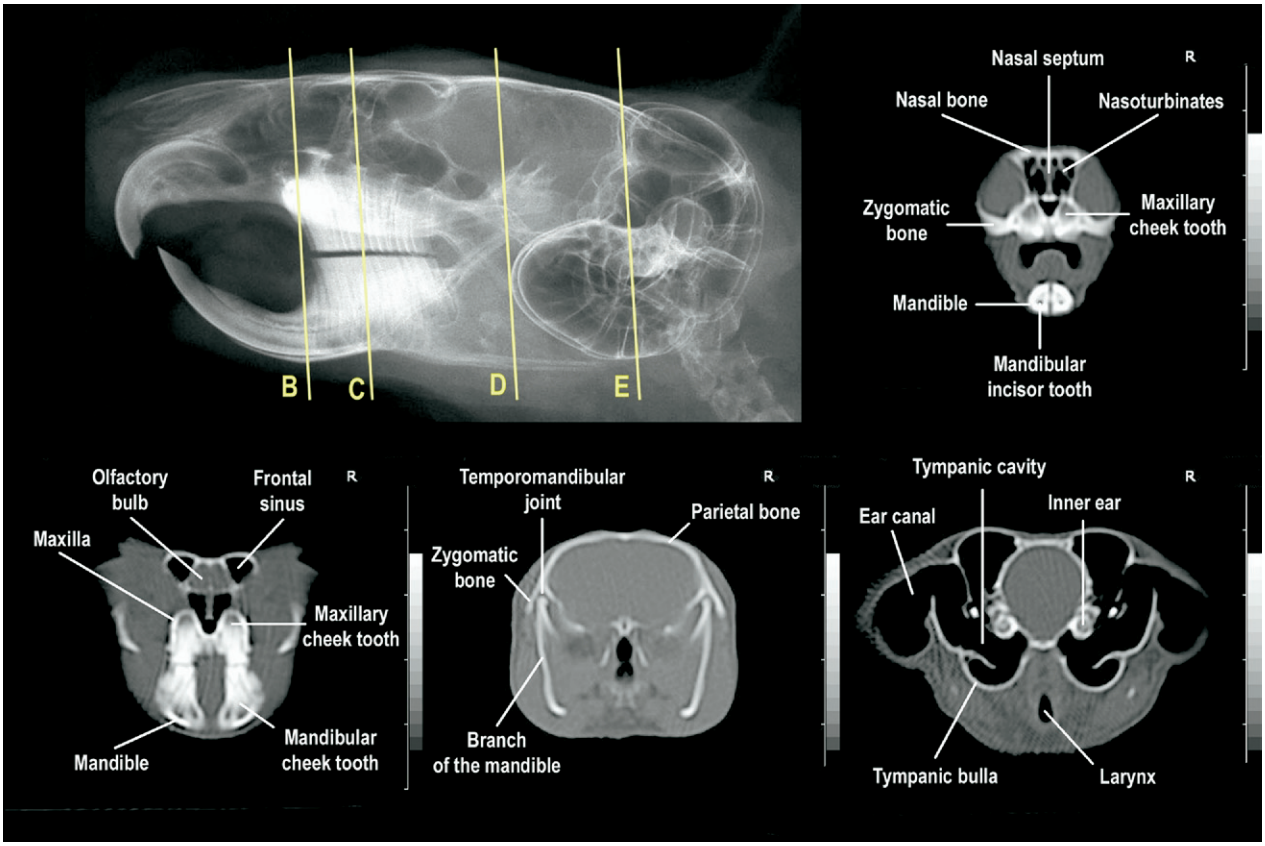

Figure 10. CT of the normal skull of a 500-g chinchilla. Scanning parameters: scan speed, 1 sec; mA, 125; kilovolt (peak), 120; slice thickness, 1 mm; reconstruction index, 0.5 mm; WL, 300; WW, 1500; image size (matrix), 512 × 512 pixels. The scout view demonstrating the scanning angles has been adapted from a radiograph of the normal skull for demonstration purposes. Reprint from: Capello V. Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

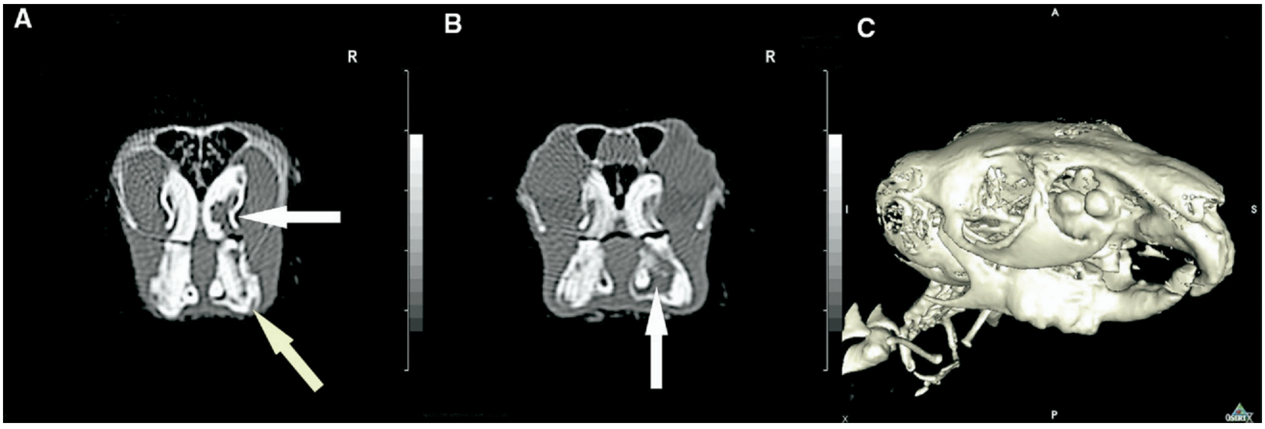

Figure 11. Severe acquired dental disease in a 4-year-old chinchilla. Scanning parameters: scan speed, 1 sec; mA, 100; kilovolt (peak), 120; slice thickness, 1 mm; reconstruction index, 0.5 mm; WL, 300; WW, 1500; image size (matrix), 512 × 512 pixels. Elongation and the typical bending of the reserve crowns and the apexes of the cheek teeth are visible, especially on the right side in (*A, B*). Caries of right maxillary cheek tooth (*C*)2 is visible in (*A*) and of right mandibular (*B*) (*arrows*). Typical deformities and bone perforation of mandibular cheek teeth are visible, especially in (*A*) (*yellow arrow*). SSD of the skull of the same chinchilla. Severe apical elongation and deformity of cheek teeth, typical of acquired dental disease in chinchillas, are highlighted with this imaging technique. This can permit earlier diagnosis of acquired dental disease, which may contribute to vague clinical signs such as epiphora. Reprinted from: Capello V, Lennox A: Clinical Radiology of Exotic Companion Mammals. Wiley-Blackwell Publishing (2008), with permission.

1 mm slices). This option provides several advantages:

- slice interval can be skipped, reducing the risk to miss some abnormalities in small patients;
- both the x-ray exposure of the patient and the fatigue of the X-ray generator can be reduced;
- the time of scanning is reduced;
- the increased number of slices produces more detailed 2-D and 3-D reconstructions.

Slice thickness, slice interval (overlap), extent of the scan, matrix and field of view are selected prior to scanning.

Interpretation of CT Data

Traditional axial CT images are challenging to interpret, and require skill and practice. Radiologists agree that axial views and supplemental sagittal, coronal, and oblique views are the most critical and sensitive for diagnosis. However, supplemental information comes from 3-D renderings, converting CT data of selected body parts into an image very similar to an image of an anatomical specimen, well within the range of interpretation of a trained clinician. Surface-rendering displays are remarkable in their ability to highlight bone abnormalities in patients with dental disease, thus allowing effective planning of the surgical approach (Fig 11). Although these displays must not be relied on as the sole modality, they are extremely valuable as an adjunct to traditional radiography.

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