Computed tomography (CT) and magnetic resonance imaging (MRI) are reliable, noninvasive techniques for use in the diagnosis of nasal disease in dogs.1,2 These techniques have been used in dogs with fungal rhinitis, nasal tumors, nonspecific rhinitis, and foreign-body rhinitis.1-9,a,14,15

Computed tomography and MRI are superior to radiography for defining the extent and character of lesions in the nasal cavities.3,6,8,10-12 In addition, these techniques are also useful for staging of tumors and during planning for surgery and radiation treatments; they also have prognostic value in dogs with nasal aspergillosis.5,13-15

In the veterinary literature, there is a paucity of publications on the use of CT and MRI for determining anatomy of the head of animals. In 1 report,16 CT scans of the normal nasal cavities and paranasal sinuses of cats were described, whereas MRI views and the cross-sectional anatomic features of the normal sinuses and nasal passages of horses were reported in another study.17 Computed tomography scans of the anatomy of the head of dogs have been described,18-23 and an atlas of MRI and CT views of dogs has been published.24 However, to our knowledge, a detailed comparative study of gross anatomic sections to identify all structures visible on CT

Art: Figure 1—Lateral computed tomography (CT) scans of transverse (a) and dorsal (b) views of the nasal cavities and paranasal sinuses of 2 clinically normal mesaticephalic dogs indicating the location (A through K) at which anatomic sections, CT scans, and magnetic resonance imaging (MRI) scans were obtained.

Received February 14, 2003.
Accepted April 8, 2003.
From the Department of Medical Imaging, Faculty of Veterinary Medicine, Ghent University, Salisburylaan 133, 9820 Merelbeke, Belgium.
The authors thank Dr. R. F. Dondelinger for assistance with magnetic resonance imaging.
Address correspondence to Dr. Saunders.
and MRI scans of the nasal cavities and paranasal sinuses of dogs has not been conducted. Thus, the objective of the study reported here was to provide a comprehensive atlas of the normal nasal cavities and paranasal sinuses in dogs by use of CT and MRI.

**Materials and Methods**

**Animals**—Two healthy Belgian Shepherd Dogs that weighed 25 and 35 kg, respectively, were used in the study. Neither dog had a history of nasal disease, and pathologic conditions were not detected during physical and radiographic exams.

**Figure 2**—Transverse anatomic section (upper left), CT scan (lower left), and MRI scans (T1-weighted MRI [top right], T2-weighted MRI [middle right], and proton-density MRI [bottom right]) of the nasal cavities and paranasal sinuses of clinically normal mesaticephalic dogs. Images were obtained at sections A through E as illustrated in Figure 1. 1 = Alar fold (ventral nasal concha). 2 = Canine tooth of maxillary dental arch. 3 = Cartilaginous nasal septum. 4 = Ciliary body of the eye. 5 = Common nasal meatus. 6 = Cribriform plate of the ethmoid bone. 7 = Dorsal nasal concha. 8 = Dorsal nasal meatus. 9 = Ectoturbinate 1. 10 = Ectoturbinate 2. 11 = Ectoturbinate 3. 12 = Ectoturbinate 4. 13 = Ectoturbinate 5. 14 = Ectoturbinate 6. 15 = Endoturbinate I. 16 = Endoturbinate II (middle nasal concha). 17 = Endoturbinate III. 18 = Endoturbinate IV. 19 = Ethmoturbinates. 20 = Falx cerebri. 21 = Frontal bone. 22 = Frontoethmoidal suture. 23 = Hard palate. 24 = Horizontal part (wing) of the vomer bone. 25 = Infraorbital canal. 26 = Incisive bone. 27 = Lateral nasal concha. 28 = Left choana. 29 = Left frontal sinus (lateral compartment). 30 = Left frontal sinus (medial compartment). 31 = Lens. 32 = Maxilla. 33 = Maxillary recess. 34 = Maxilloturbinate crest (conchal crest). 35 = Middle nasal meatus. 36 = Nasal bone. 37 = Nasopharyngeal meatus. 38 = Nasoturbinate crest (ethmoidal crest). 39 = Olfactory bulb of the brain. 40 = Orbit. 41 = Orbital lamina of the ethmoid bone forming the medial wall of the maxillary recess. 42 = Palatine canal. 43 = Palatine fissure. 44 = Palatine process of the incisive bone. 45 = Palatine process of the maxillary bone. 46 = Perpendicular lamina of the ethmoid bone (ventral part of osseous nasal septum). 47 = Presphenoid bone. 48 = Right caudal recess of the right nasal cavity (sphenoid sinus) occupied by endoturbinate IV. 49 = Right choana. 50 = Right frontal sinus (lateral compartment). 51 = Right frontal sinus (medial compartment). 52 = Right pterygoid muscle. 53 = Right upper molar. 54 = Septal process of the frontal bone (dorsal part of osseous nasal septum). 55 = Septal process of the vomer bone. 56 = Sphenoidal process of the palate bone. 57 = Sphenoidal process of the palate bone. 58 = Septal process of the vomer bone. 59 = Septal process of the vomer bone. 60 = Septum between the nasal cavities and paranasal sinuses. 61 = Septum between the nasal cavities and paranasal sinuses. 62 = Soft palate. 63 = Sphenoid process of the palate bone. 64 = Spiral pterygoid muscle. 65 = Straight fold (dorsal nasal concha). 66 = Uncinate process. 67 = Ventral nasal concha. 68 = Ventral nasal meatus. 69 = Vomer. 70 = Vomeronasal organ.
examinations. Four radiographic images were obtained for each
dog (dorsoventral and lateral radiographs of the entire skull,
dorsoventral intraoral radiograph of the nasal cavities and max-
illa, and rostrocaudal radiograph of the frontal sinuses).

**CT and MRI**—Dogs were sedated by IV administration
of fentanyl (0.005 to 0.01 mg/kg) and droperidol (0.25 to
0.5 mg/kg). Anesthesia was induced by IV administration of
thiopental sodium (8 mg/kg). Dogs were intubated, and anes-
thetia was maintained by administration of 1.5 to 2.0% halothane. The CT and MRI examinations were then per-
formed on the anesthetized dogs.

The first dog was positioned in ventral recumbency for
CT and MRI examinations, and transverse slices of the nasal
cavities and paranasal sinuses were obtained. First, CT was
performed by use of a third-generation CT scanner. Technical
settings were 120 kV and 130 mA. Five-millimeter-thick con-
tiguous slices were obtained from the caudal aspect of the
frontal sinuses to the nares. Hard copies were printed by use
of a bone setting (window width, 3,500 Hounsfield units;
window level, 900 Hounsfield units). Immediately after CT
was completed, MRI was performed by use of commercially
available equipment. A series of 5-mm transverse slices was
obtained from the caudal aspect of the frontal sinuses to the
nares. The T1-weighted (repetition time [TR], 400 millisec-
onds; echogenicity time [TE], 19 milliseconds), T2-weighted
(TR, 4,000 milliseconds; TE, 80 milliseconds), and proton-
density (TR, 4,000 milliseconds; TE, 18 milliseconds) images
were acquired. Acquisition matrix was 256 X 224.

The second dog was positioned in dorsal recumbency with
the head perpendicular to the table; this dog was used to obtain dorsal (ie, horizontal) images of the nasal cavities and paranasal sinuses. The same CT and MRI protocol was used in both dogs.

Comparison of CT and MRI images and anatomic structures—At the completion of the MRI examination, each dog was injected IV with heparin (via a cephalic vein). The dogs were then euthanatized.

A 4% solution of formaldehyde was perfused IV (via a jugular vein) immediately after each dog was euthanatized. The head of each dog was removed at the atlantooccipital joint, and the skin of the cranium, mandibles, and temporal muscles were removed. Each skull was placed in a nitric acid solution for decalcification for 2 weeks; skulls were then embedded in gelatin. Each skull was sectioned into 5-mm-thick sections by use of a stainless-steel knife. Each anatomic section was photographed and compared with the corresponding CT and MRI views. From this collection, 11 (9 transverse and 2 dorsal) representative matched series of images of the nasal cavities and paranasal sinuses were selected from rostral to caudal (9) and dorsal to ventral (2) regions. Bony structures and soft tissues were identified on the anatomic sections. The identified structures were subsequently located on the corresponding CT and MRI scans. Nomenclature used for designating all structures was in accordance with official anatomic terms.25

Results
Nine representative transverse planes extending from the olfactory bulb of the brain to the alar cartilage were selected in the first dog, and 2 dorsal planes of the nasal cavities were selected in the second dog (Fig 1). Computed tomography and MRI (T1-weighted, T2-weighted, and proton-density sequences) scans of the nasal cavities were compared with the corresponding anatomic sections (Fig 2 and 3).

Most parts of the nasal cavities and paranasal sinuses could be identified on the anatomic sections. Several adjacent structures that remained on the skull, such as the olfactory bulb of the brain, orbits, canine teeth, nasopharynx, soft palate, salivary glands, and pterygoid muscles, were quite distinct. The various facial bones that form the outer wall of the nasal cavities as well as the inner nasal conchae, septa, meatuses, and all endo- and ectoturbinates could easily be identified. The medial and lateral parts of the frontal sinuses and the maxillary recess were also visible.

On the CT scans, it was possible to identify various structures of the nasal cavities and paranasal sinuses. However, we were less able to distinguish between surrounding soft-tissue structures on the CT scans.

It was difficult to identify facial bones on the MRI scans. In contrast, the conchae, conchal septa, and turbinates were easy to see because of the distinct mucosal covering. The surrounding soft-tissue structures were also clearly visible on MRI scans.

Discussion
Although information on CT and MRI scans of the nasal cavities and frontal sinuses of dogs exists,18,19,24 a detailed anatomic description of those images in clinically normal dogs is lacking. The complexity of radiographs attributable to superimposition of the facial bones and nasal turbinates can be overcome by use of single-plane images of the nasal cavities and frontal

Figure 3—Dorsal anatomic section (upper left), CT scan (upper right), and MRI scans (T1-weighted MRI [bottom left], T2-weighted MRI [bottom middle], and proton-density MRI [bottom right]) of the nasal cavities and paranasal sinuses of clinically normal mesaticephalic dogs. Images were obtained at sections J and K as illustrated in Figure 1. See Figure 2 for key.
sinuses. Images through the transverse, dorsal, or sagittal plane provide detailed anatomic information. The sagittal plane was not used in this study, because it does not permit symmetric comparison between the left and right sides of the nose. The dorsal plane is most appropriate for use in determining the integrity of the cribiform plate in dogs with nasal tumors or nasal aspergillosis. Therefore, a soft-tissue window was not used to do not contain soft-tissue structures other than the mucosa.24 Images through the dorsal plane also provide a more general view of the entire nasal cavities, allowing easier characterization of disease processes. This differentiation is also possible by use of images obtained via the transverse plane. Moreover, images for the transverse plane can easily be obtained with a dog positioned in ventral recumbency, and this allows better evaluation of the nasal turbinates, which is essential for the diagnosis of diseases that affect the nasal region. Therefore, the transverse plane is the reference plane for the assessment of nasal pathologic changes.

Magnetic resonance imaging allows investigators to make multiplanar images without repositioning the dog.25 It is also possible to obtain dorsal, sagittal, and transverse views of the same dog by use of CT, but this requires repositioning of the dog, which may be complicated. An alternative method to achieve CT images in various planes without repositioning the dog is by way of dorsal and sagittal reconstructions, although their quality is inferior to that of native images.

The CT examinations were reviewed only for a bone window. The nasal cavities and paranasal sinuses do not contain soft-tissue structures other than the mucosa. Therefore, a soft-tissue window was not used in our anatomic study. A soft-tissue window in combination with examinations conducted by use of contrast agents may be useful in a nasal cavity with pathologic changes to enable differentiation between fluid and soft tissue or to define more accurately the nature of an abnormal soft-tissue structure.26,27 However, in pathologic conditions, the nasal cavities often contain many structures of differing physical densities (ie, bone, cartilage, mucosa, and air), which makes most CT measurements of attenuation values unreliable.28 In contrast to CT, MRI allows differentiation between the nasal mucosa and other soft tissues or fluid.

Analysis of results of the study reported here indicates that all nasal structures can be evaluated by use of CT or MRI. However, differentiation between the various layers of the nasal mucosa is not possible with these techniques.

Computed tomography and MRI are increasingly available to veterinarians. Axial CT, MRI, and radiography require at least 15 minutes for a complete examination and must be performed in anesthetized animals. Using helical CT, the time of the examination is considerably reduced (2 to 4 minutes), and the procedure may be performed in animals that are deeply sedated.29 Advantages of CT over MRI are lower cost and a reduced amount of time to conduct an examination. Advantages of MRI over CT include the use of multiplanar capabilities.

The information reported here should serve as a baseline reference for evaluation of CT and MRI scans of the nasal cavities and paranasal sinuses of dogs. It can be used to assist clinicians in interpretation of pathologic conditions of the nasal region.

References
20. George F, Smallwood J. Anatomic atlas for computed