Computed tomography and cross-sectional anatomy of the thorax in clinically normal dogs

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Objective—To provide a detailed anatomic description of the thorax in clinically normal dogs by means of computed tomography.

Animals—Four clinically normal adult German Shepherd Dogs weighing 28 to 37 kg.

Procedure—Dogs were anesthetized and positioned in ventral recumbency for computed tomographic (CT) examination of the thorax. A CT image from the thoracic inlet to the diaphragm was made by use of a third-generation scanner with a slice thickness of 5 mm. Individual images were reviewed by use of soft tissue (window width, 250 Hounsfield units; window level, 35 Hounsfield units) and lung (window width, 1,000 Hounsfield units; window level, –690 Hounsfield units) settings. One dog, weighing 28 kg, was euthanatized, bound on a wooden frame in the same position as used for CT examination, and frozen at –14°C until solid. By use of an electric band saw, the frozen thorax was sectioned at 10-mm-thick intervals. Slab sections were immediately cleaned, photographed, and compared with corresponding CT images.

Results—Anatomic sections were studied, and identified anatomic structures were matched with structures on corresponding CT images. Except for some blood vessels and details of the heart, most of the bony and soft tissue structures of the thorax discerned on anatomic slices could be found on matched CT images.

Conclusions and Clinical Relevance—Because CT images provide detailed information on most structures of the canine thorax, results of our study could be used as a guide for evaluation of CT images of the thorax of dogs with thoracic diseases. (Am J Vet Res 2005;66:512–524)

During recent years, computed tomography of the thorax has become established as an important radiologic procedure.1 Computed tomographic (CT) displays of the lungs, mediastinum, pleural cavity, and chest wall in a transverse plane provide unique diagnostic information that is unobtainable with conventional radiographic techniques.1 Compared with conventional radiography, computed tomography allows better distinction among specific tissue densities in the thorax and detection of subtle changes in organ size, shape, margin contour, and position.2,4

In human medicine, use of computed tomography plays a key role in the diagnosis and evaluation of various thoracic syndromes and diseases such as pneumothorax; pleural and pericardial effusion; collapse of a lung lobe; congenital anomalies; pulmonary parenchymal and bronchial diseases; cysts; abscesses; and primary or metastatic neoplasia of the lungs, pleura, mediastinum, lymph nodes, and chest wall.2,3,4 Furthermore, computed tomography is a useful preoperative technique, a precise staging tool, and improves the use of biopsies by allowing detection of lesions not identifiable by fluoroscopy and determination of the location of high-risk masses that are close to cardiovascular structures.2,4,5,6

The use of computed tomography in diagnosing thoracic diseases in veterinary medicine is in full exploration,1,2,6 and an increasing number of published clinical reports1,2,6,7 are found involving thoracic computed tomography. Accurate interpretation of CT images of the thorax requires a thorough knowledge of cross-sectional anatomy of that region. A few papers8–10 on CT anatomy of the thorax of clinically normal animals are available. Authors of 1 paper11 described CT and cross-sectional anatomy of the thorax of clinically normal cats, and authors12 of another paper reported CT anatomy of the thorax of Nubian goats. The purpose of the study reported here was to identify structures that are visible on CT images of the canine thorax by means of a detailed color atlas consisting of a series of labeled anatomic photographs. Although some publications13–15 have been published on cross-sectional CT anatomy of the canine thorax, in the present study we combined the study of CT and gross anatomic sections, which provides more detailed and additional information.

Materials and Methods

Animals—Four clinically normal adult German Shepherd Dogs weighing 28 to 37 kg were used for this study. Before the onset of CT examination, a clinical and radiographic examination of the thorax of each dog was performed, which included obtaining right and left lateral radiographic views of the thorax.

Computed tomography—Dogs were sedated by use of medetomidine hydrochloride16 (40 to 50 µg/kg of body weight, IM) and anesthetized with thiopental sodium17 (8 mg/kg, IV). After intubation, anesthesia was maintained with 1.5% to 2% halothane.18 Intermittent positive-pressure ventilation was applied to the lungs to decrease motion artifacts caused by irregular or fast respiration of the dogs. Respiratory rate was set at 6 breaths/min.

Dogs were positioned in ventral recumbency on the scanning table with forelimbs in extension. A lateral survey view was made by use of a third-generation CT scanner.19 Transverse 5-mm-thick contiguous CT images of the thorax from the thoracic inlet to diaphragm were obtained. Settings for the CT image technique were 120 kV and 100 mA. Hard
copied were printed on x-ray film by use of a soft tissue setting (window width, 250 Hounsfield units; window level, 35 Hounsfield units) and a lung setting (window width, 1,000 Hounsfield units; window level, −690 Hounsfield units).

**Comparison of CT and anatomic images**—At the end of CT examination, 1 dog weighing 28 kg was euthanatized for reasons unrelated to thoracic disease. For euthanasia, a combination of embutramide, mebenzoniumiodide, and tetracaine (0.3 mL/kg of body weight) was injected IV during anesthesia. After euthanasia, the dog was bound on a wooden frame in the same position used for scanning and frozen at −14°C until solid. The frozen cadaver was placed on the movable table of an electric band saw, and serial transverse sections were cut approximately 10 mm apart, beginning at the thoracic inlet and ending at the diaphragm. Slices were numbered and gently cleansed of debris with cold tap water and light brushing. They were immersed in water, and the cranial surface of each section was photographed immediately (ie, before thawing). Photographs were studied, and identifiable anatomic structures were labeled with the aid of texts on canine anatomy. For each anatomic slice, a corresponding anatomic image was chosen on the basis of similar appearance. Identified structures were subsequently located on CT images. Nomenclature used for designating all structures was in accordance with official anatomic terminology. From this collection, 24 representative matched pairs of images extending from the level of the sternal manubrium to the most caudal part of the lungs were selected.

**Results**

The 24 selected levels, at which anatomic sections and their corresponding CT images were made, are indicated on a lateral survey view of the thorax of a German Shepherd (Figure 1). Identifiable anatomic structures are labeled on cadaver sections and corresponding CT images (Figure 2).

On anatomic sections, various structures of the canine thorax could be identified. Respiratory tract structures including the trachea, tracheal bifurcation (carina), principal bronchi, lobar bronchi, and various lobes of the left and right lungs were clearly visible.

Large vessels such as left and right external jugular veins, brachiocephalic veins, common carotid arteries, subclavian and axillary arteries and veins, costocervical trunks and veins, and the cranial vena cava could be seen in the cranial mediastinum. Identification of these vessels could be ascertained by comparing cross-sectional images on successive levels. Other intrathoracic vascular structures including the thick-walled aortic arch, ascending and descending aorta, pulmonary arteries and veins (located ventral to corresponding principal bronchi), left coronary artery, internal thoracic arteries and veins, and the aortic arch could readily be seen in the cranial mediastinum. Identification of these vessels could be ascertained by comparing cross-sectional images on successive levels.

Intrathoracic structures such as the heart with its chambers and valves, esophagus, longus colli muscle, and transverse thoracic muscle could easily be distinguished. Sternal lymph nodes were identified ventral to the transversus thoracis muscle and dorsal to the manubrium of the sternum. Cranial mediastinal lymph nodes were discerned lateral to the cranial vena cava.

Tracheobronchial lymph nodes could be observed ventral to the tracheal bifurcation.

Various parts of the thoracic wall including the sternum, ribs with the intercostal muscles, and thoracic vertebrae enclosing the spinal cord were clearly visible. Other identifiable structures were the scapulae, nuchal ligament, and muscles of the thorax and proximal part of the forelimbs. In caudal sections, the liver portal and hepatic blood vessels, gallbladder, stomach, descending duodenum, and diaphragm could be discerned.

In the 4 dogs examined, most of the previously mentioned structures of the thorax could be identified on CT images at the soft tissue setting. The heart silhouette could be observed, but cardiac chambers, valves, and interventricular septum were not visible.

In any dog, it was impossible to distinguish the nuchal ligament or the left coronary artery, intercostal veins, vertebral vessels, lymph nodes, lobar bronchi, and various lobes of the lungs. In the cranial mediastinum, the left and right axillary arteries and right costocervical trunk and vein could not be discerned. Furthermore, portal and hepatic vessels, diaphragm, and descending duodenum were not visible in the most caudal CT images of the 4 dogs. The left costocervical trunk and contours of the gallbladder could be discerned in 2 of the 4 dogs. The ascending aorta, left costocervical vein, left and right axillary vein, main bronchus of the accessory lobe of the right lung, and left and right pulmonary veins could be identified in 3 of the 4 dogs by comparing their position on the corresponding anatomic images. In all 4 dogs, most parts of the stomach could be seen.

On CT images obtained at the lung setting, only various structures of the respiratory tract and some large vessels were distinct in all dogs. The tracheobronchial tree including the trachea, tracheal bifurcation, principal bronchi, lobar bronchi, and various lobes of the left and right lung could easily be discerned. In 1 dog, however, the main bronchus of the accessory lobe of the right lung could not be discerned. Large intrathoracic vessels such as the descending aorta, caudal vena cava, and major pulmonary arteries...
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and veins could be identified in all instances. Of the heart and liver, only contours were visible. The presence of air in the esophagus and in cardia and fundus of the stomach allowed the position of these organs to be determined on CT images. However, it was impossible to see the cardiac sphincter and all parts of the stomach in any dog.

Discussion

Results of our study indicate that the use of anatomic sections is helpful for identifying a large number of thoracic structures that are visible on CT images of the canine thorax. Only nerves and small vessels could not be discerned. Anatomic images made in our study matched closely with corresponding CT images.
images, except for the more caudal position of the scapulae on CT images. This indicates that the forelimbs were less extended during CT examination than during the freezing process.

Thoracic CT images were evaluated by use of a lung and a soft tissue (mediastinal) setting. Various structures of the respiratory tract were most distinct on the lung window. Still, for detection of pathologic processes, the lungs should be evaluated with lung and soft tissue windows to avoid missing lesions excluded by window settings. For a complete examination of the lungs, it is recommended to scan the patient in various positions, depending on the area of interest, because atelectasis and gravitational pulmonary-flow differences may alter the density of the dependent lung. Assisted suspended inspiration may also be needed to better assess overall lung density.

In our study, it was impossible to identify various parts of the heart on soft tissue CT images or to define details of the lungs on lung-window CT images as a result of motion artifacts. Because thoracic CT investigations were performed on living dogs, cardiovascular and respiratory movements could not be avoided. Applying intermittent positive-pressure ventilation to the lungs decreased motion artifacts caused by irregular or fast respiration of each dog. Computed tomographic images were taken during the expiratory pause of dogs as described by Henniger et al. Hyperventilation is another method that has been described for decreasing respiratory movements during performance of intrathoracic biopsies. Use of newer scanning equipment, such as helical (spiral) computed tomography, could also minimize these motion artifacts.

Unfortunately, few veterinarians currently have access to spiral computed tomography. In the past few years, high-resolution computed tomography has been found useful for evaluation of the lungs and for diagnosis of a variety of pulmonary diseases. Until now, little information has been published on the use of computed tomography for pulmonary evaluation in animals. Nevertheless, applications of pulmonary computed tomography in dogs and cats appear to be similar to those in humans and the role of computed tomography for diagnostic and investigative studies of the heart and lungs will likely progress as access to better equipment improves.

A number of vessels identified on anatomic sections could not be discerned on corresponding CT images. Intravascular administration of contrast media might be helpful in identification of vascular structures on soft tissue CT images. In humans, computed tomography following an IV bolus of contrast medium has replaced arteriography for the diagnosis of most intrathoracic vascular lesions. Intravascular contrast agents are also useful in defining the extent of mediastinal masses and their relation to delicate structures such as major vessels or the heart.

In our study, IV administration of contrast medium was not used because the aim was to describe plain CT images made by standard procedures. As a result of costs and anesthetic risks, thoracic computed tomography is not yet used routinely in veterinary medicine. At present, this technique is indicated in carefully selected patients, but in the future, its use in animals as a diagnostic and preoperative tool for detection of thoracic diseases and as a guide for performing thoracic biopsies will undoubtedly evolve. Results of our study indicate that CT images provide detailed information on most structures of the canine thorax. Therefore, our description of CT anatomy of the canine thorax could be used for evaluation of CT images of dogs with thoracic disease.

References


