Use of helical computed tomography for measurement of thyroid glands in clinically normal cats

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Objective—To determine the dimensions and volume of thyroid tissue in clinically normal cats by use of computed tomography.

Animals—8 cats.

Procedure—Helical computed tomography images (2-mm collimation) were acquired from the cranial aspect of the second cervical vertebra through the caudal aspect of the fourth cervical vertebra. Data were acquired before contrast medium administration (n = 7 cats) and immediately after contrast medium enhancement (1 cat). Length, width, and height measurements of each thyroid lobe were made by use of transverse, dorsal, and sagittal plane images. Thyroid lobe volume was estimated by use of 3 methods.

Results—All thyroid lobes were histologically normal. Mean dimensions for a thyroid lobe were 16.5 × 2.00 × 4.31 mm (length × width × height) using only data from transverse images. Mean thyroid lobar volume was 113.75 mm^3 using the sum of areas method. Mean total volume of thyroid tissue was 215.25 mm^3 using the sum of areas method.

Conclusions and Clinical Relevance—Results may be useful for computed tomography evaluation of abnormal thyroid glands in cats, which warrants investigation. (*Am J Vet Res* 2006;67:467–471)

Hyperthyroidism is a common disease in cats. Approximately 70% of cats with hyperthyroidism have bilateral thyroid gland enlargement.[1–3] Hyperthyroidism caused by thyroid gland neoplasia develops in only 1% to 2% of cats.[1,4]

In cats, the thyroid gland is bilobed and located lateral to the trachea.[5] The thyroid gland consists of separate masses (lobes) that are not connected by an isthmus[5,6]; in humans, the thyroid gland has an isthmus.[7]

In humans, normal thyroid tissue is hyperattenuating to surrounding tissues by use of precontrast CT.[7–9] The high attenuation of normal thyroid tissue is directly associated with its iodine concentration.[9–12] In clinically normal cats, thyroid tissue is hyperattenuating to surrounding soft tissues with precontrast CT numbers of 123.2 Hounsfield units (95% confidence interval, 119.4 to 127.1 Hounsfield units).[13]

In humans, volume determination of thyroid glands is easy, reliable, and repeatable.[14] Compared with ultrasonography, CT volume determination of large thyroid glands caused by goiter in 27 people was more reproducible.[15] Another study[16] estimated normal thyroid gland size by use of the thyroid gland-to-trachea ratio. Use of the thyroid gland-to-trachea ratio was easier than calculating the volume of the entire thyroid gland. In clinically normal cats, the size and volume of thyroid glands have been determined by use of ultrasonography.[17] Ultrasonographically, thyroid glands in hyperthyroid cats were larger than thyroid glands in clinically normal cats.[17]

Ablation of hyperactive thyroid tissue in cats by use of iodine 131 (^{131}I) is common. However, the optimal method of ^{131}I dose determination is controversial.[1] Methods include measuring the kinetics of ^{131}I uptake by the thyroid gland[18]; estimating volume on the basis of thyroid scintigraphy[18,19]; use of a combination of clinical signs, thyroid gland size, and magnitude of serum thyroxine concentration[20]; and use of an empirical dose of 148 to 185 MBq (4 to 5 mCi) of ^{131}I.[21,22] An accurate method for determining the volume of thyroid tissue in cats may help eliminate some of the controversy.

Use of CT is increasing in veterinary medicine. Knowing the dimensions of thyroid glands in clinically normal cats should aide in the evaluation of the cervical region. The purpose of the study reported here was to determine the dimensions and volume of thyroid tissue in clinically normal cats by use of CT.

Materials and Methods

Cats—Eight clinically normal adult sexually intact female cats (weighing 2.55 to 2.90 kg) were studied. These cats were used in other studies.[13,23,a,b] Cats were clinically normal on the basis of CBC, serum biochemical analyses, serum T_4 concentration, and urinalysis results. The Animal Care and Use Committee at the Ohio State University approved the study.

Anesthesia—Each cat was sedated with acepromazine maleate (0.023 mg/kg, IM) and ketamine hydrochloride (1.36 mg/kg, IM). Approximately 15 minutes after administration of acepromazine and ketamine, cats were anesthetized with isoflurane in oxygen. Isoflurane in oxygen was administered with a face mask until an endotracheal tube could be placed. Anesthesia was maintained with isoflurane in oxygen through the endotracheal tube.

CT Computed tomography
mgI Milligrams of iodine
^{99m}Tc Technetium Tc 99m
T4 Thyroxine

Received May 20, 2005.
Accepted July 8, 2005.

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Supported by a grant from The Ohio State University Seed Grant Program.
Presented at the American College of Veterinary Radiology Annual Scientific Meeting, Chicago, December 2002.

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Table 1—Dimensions of thyroid lobes in 8 clinically normal cats measured in 3 CT imaging planes.

Imaging plane		Length	Width	Height
Transverse	Right	16.75 ± 1.49 (15.51 – 17.99)	2.00 ± 0.76 (1.37 – 2.63)	4.63 ± 0.52 (4.19 – 5.06)
	Left	16.25 ± 2.92 (13.81 – 18.69)	2.00 ± 0.53 (1.55 – 2.45)	4.00 ± 0.93 (3.23 – 4.77)
	Both	16.50 ± 2.25 (15.30 – 17.70)	2.00 ± 0.63 (1.66 – 2.34)	4.31 ± 0.79 (3.89 – 4.74)
Sagittal	Right	17.00 ± 2.56 (14.86 – 19.14)	NA	4.13 ± 0.64 (3.59 – 4.66)
	Left	17.13 ± 1.81 (15.61 – 18.64)	NA	4.00 ± 1.41 (2.82 – 5.18)
	Both	17.06 ± 2.14 (15.92 – 18.20)	NA	4.06 ± 1.06 (3.50 – 4.63)
Dorsal	Right	16.57 ± 4.04 (12.84 – 20.30)	2.63 ± 0.74 (2.00 – 3.25)	NA
	Left	17.00 ± 1.91 (15.23 – 18.77)	2.50 ± 1.07 (1.61 – 3.39)	NA
	Both	16.79 ± 3.04 (15.03 – 18.54)	2.56 ± 0.89 (2.09 – 3.04)	NA

Values are given as mean ± SD (95% confidence interval). NA = Not applicable.

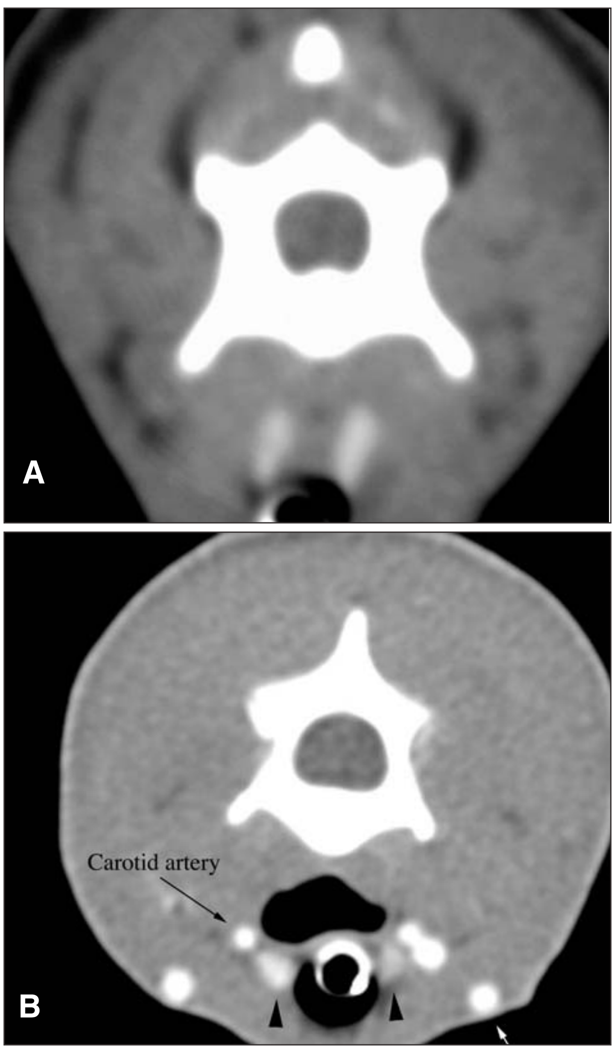

Figure 1—Transverse CT images of the cervical area of a clinically normal cat. A—Image obtained at the middle aspect of the third cervical vertebra before administration of contrast medium (iohexol). Thyroid tissue, dorsolateral to the trachea, is hyperattenuating to surrounding tissue. The CT images were viewed at a window of 300 and a level of 50. B—Image obtained at the cranial aspect of the fourth cervical vertebra after administration of contrast medium. Each thyroid lobe (black arrowheads) is lateral to the trachea. White arrow = A jugular vein.

CT—Cats were positioned in sternal recumbency. All data were collected by use of a fourth-generation CT scanner.[c] The acquisition parameters were as follows: kV peak, 120 (n = 7) or 130 (1); mA, 125 (8); field of view, 80 mm; algorithm, standard; collimation, 2-mm spiral; and pitch, 1.25. A lateral scout image of the cervical area was obtained for image planning. Slices were acquired from the cranial aspect of the second cervical vertebra through the caudal aspect of the fourth cervical vertebra with transverse images oriented perpendicular to the cervical aspect of the vertebral column. Data were acquired in 7 cats before contrast medium was administered. Iohexol[d] (240 mgI/mL) was given at a dose of 0.45 mL/kg, IV, via a cephalic vein catheter as part of an abdominal CT study.[a] After the abdominal study, delayed contrast medium–enhanced images of the cervical area were obtained in 8 cats. A second injection of iohexol (240 mgI/mL) was made and immediate postcontrast medium–enhanced images were acquired in 8 cats.

Image analysis—Measurements were obtained by use of precontrast medium–enhanced (n = 7 cats) or delayed contrast medium–enhanced images (1). By use of transverse images, the length of the thyroid lobe was determined by counting the number of slices that contained thyroid tissue and multiplying by the slice thickness (2 mm). The maximum height and width of each thyroid lobe were measured by use of electronic calipers included with the CT scanner software. Measurements were recorded in millimeters.

Multiplanar reformatted images of the cervical area were made by use of CT scanner software. Dorsal and parasagittal planes were reformatted with an index of 2 mm. By use of dorsal plane images, the maximum length and width of each thyroid lobe were measured with electronic calipers. Data from 1 cat were acquired while the CT gantry was tilted, and the resulting dorsal plane reformatted images were not suitable for obtaining measurements. By use of parasagittal plane reformatted images, the maximum length and height of each thyroid lobe was measured with electronic calipers. Measurements were recorded in millimeters.

Thyroid lobe volume was calculated by use of 3 methods. First, on each transverse slice that contained thyroid tissue, the margin of each thyroid lobe was traced freehand. The CT scanner software calculated the area within the region of interest. All regions of interest were added and multiplied by slice thickness to determine thyroid gland volume. The first method is called the sum of areas method. The second method, called transverse ellipse volume, used dimensions obtained only from the transverse images to calculate thyroid lobe volume and used the following formula for a prolate ellipse:

$$\text{Volume} = \text{length} \times \text{width} \times \text{height} \times \pi/6$$

The third method, called maximum ellipse volume, used the maximum dimension (length, width, and height) obtained from either the transverse, dorsal, or parasagittal images. For

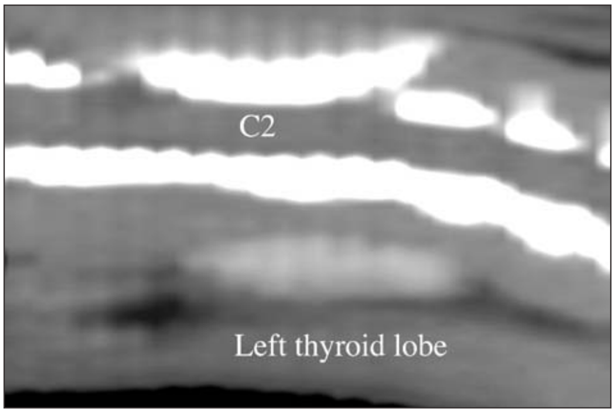

Figure 2—Sagittal plane reformatted CT image of the cervical area of a clinically normal cat obtained through the left thyroid lobe before administration of contrast medium. Notice that the thyroid tissue is hyperattenuating to surrounding tissue. The CT images were viewed at a window of 400 and a level of 50. C2 = Second cervical vertebra.

instance, if the following dimensions were obtained—transverse (length, 16.75 mm; width, 2 mm; and height, 4.5 mm), sagittal (length, 17 mm and height, 4 mm), and dorsal (length, 16.5 mm and width, 2.5 mm)—then the maximum dimension would be length, 17 mm; width, 2.5 mm; and height, 4.5 mm). Volume was calculated by use of the prolate ellipse formula. The total thyroid gland volume for each cat was determined by adding the volume of the left and right thyroid lobes.

Histologic specimens—After cats were euthanatized, thyroid glands were removed and fixed in neutral-buffered 10% formalin. Thyroid tissue was embedded in paraffin, and 4-µm sections were cut and stained with H&E stain.

Statistical analysis—Descriptive statistics were calculated for the thyroid lobe dimensions measured by use of the previously mentioned methods. Descriptive statistics were calculated for thyroid lobe and gland volume. For each thyroid lobe dimension and for thyroid lobe volume, comparison of means was performed by use of a paired *t* test; a value of $P < 0.05$ was considered significant.

Results

Thyroid glands from all 8 cats were histologically normal. No significant ($P > 0.254$) difference in length was detected when data obtained from each plane were compared (**Table 1**; **Figures 1–3**). Width measurements made by use of dorsal plane reformatted images were significantly ($P = 0.015$) larger than measurements made by use of transverse images. Height measurements made by use of parasagittal plane reformatted images were not significantly ($P = 0.432$) different from measurements made by use of transverse images.

Thyroid lobe volume calculated from data obtained by use of transverse images was significantly less than thyroid lobe volume calculated by use of the maximum dimension and the sum of areas methods ($P < 0.001$ and $P = 0.001$, respectively; **Table 2**). Thyroid lobe volume calculated by use of the maximum dimension and the sum of areas methods were not significantly ($P = 0.848$) different.

Discussion

Results of the study reported here established size and volume of thyroid tissue in clinically normal cats by use of CT. Mean thyroid lobe dimensions in clinically normal cats were 16.5 × 2.00 × 4.31 mm (length × width × height as determined by transverse images), yielding a mean lobar volume of 113.75 mm^3 (as deter-

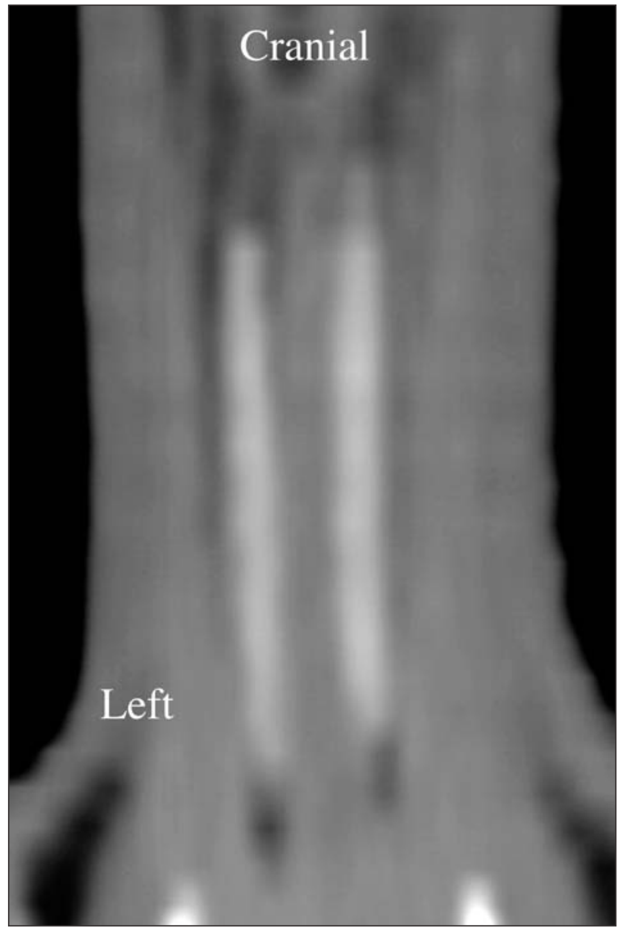

Figure 3—Dorsal plane reformatted CT image of the cervical area of a clinically normal cat, obtained through the thyroid lobes before administration of contrast medium. Thyroid tissue is hyperattenuating to surrounding tissue. The CT images were viewed at a window of 400 and a level of 50.

Table 2—Mean ± SD (95% confidence interval) volume of thyroid lobes and thyroid glands (total) estimated by use of 3 methods on the basis of CT data from 8 clinically normal cats.

Method		Volume (mm^3)
Sum of areas	Right	107.25 ± 44.75 (69.84 – 144.66)
	Left	120.25 ± 56.07 (73.38 – 167.12)
	Both	113.75 ± 49.46 (87.39 – 140.11)
	Total	215.25 ± 111.03 (138.81 – 292.19)
Transverse ellipse	Right	82.63 ± 37.78 (51.04 – 114.21)
	Left	67.50 ± 23.90 (47.52 – 87.48)
	Both	75.06 ± 31.52 (58.26 – 91.86)
	Total	147.65 ± 57.09 (108.09 – 187.22)
Maximum ellipse	Right	117.50 ± 45.28 (79.65 – 155.35)
	Left	113.75 ± 58.93 (64.49 – 163.02)
	Both	115.63 ± 50.80 (88.55 – 142.70)
	Total	231.23 ± 105.32 (158.25 – 304.22)

Both = Mean volume of left and right thyroid lobes. Total = Mean volume of thyroid tissue in each cat.

mined by the sum of areas method). The mean total volume of thyroid tissue was 215.25 mm^3. These measurements can be made by use of precontrast medium–enhanced CT images because thyroid tissue in cats is hyperattenuating to the surrounding tissues.[13] The dimensions and volume estimates of thyroid lobes in clinically normal cats have been determined by use of ultrasonography.[17] The dimension of the thyroid lobes and the volumes estimates by use of ultrasonography were as follows: length, 20.4 mm; width, 2.5 mm; height, 3.2 mm; lobar volume, 85 mm^3; and total thyroid volume, 169 mm^3 (as determined by transverse ellipse).[17] Comparing data obtained by use of ultrasonography to our data, the dimensions are similar. Depending on the method of thyroid volume determination by use of CT, the ultrasonographic thyroid volume estimates are larger (ultrasonography prolate ellipse vs CT transverse ellipse) or smaller (ultrasonography prolate ellipse vs CT maximum prolate ellipse or CT sum of areas).

Several methods were used to measure thyroid lobes. Use of transverse images is the most straightforward method for obtaining thyroid lobe measurements, and we recommend use of this imaging plane for obtaining measurements. However, if transverse images were not made perpendicular to the long axis of the thyroid lobes, slice obliquity would lead to overestimation of thyroid lobe height and underestimation of thyroid lobe length. Volume measurements obtained by use of the sum of areas method is likely more accurate than using linear dimensions and prolate ellipse formula. In our study, volume measurements obtained by use of the transverse ellipse method were significantly smaller than those obtained by use of the sum of areas method or the maximum ellipse method. Use of the prolate ellipse method would underestimate thyroid gland volume. Whether the significant difference detected is biologically relevant needs to be evaluated by comparing normal and abnormal thyroid lobes. No significant difference was detected between the volume estimates made by use of the sum of areas and the maximum ellipse methods. Reformatted images are not required for the sum of areas method as they are for the maximum ellipse method. Lower spatial resolution of reformatted CT images, compared with the original CT image, may make accurate linear measurements more difficult. An alternative to creating reformatted images of the cervical area is to reposition the cat in the CT gantry to directly acquire dorsal or sagittal plane images. The small size of cats makes this possible. The sum of areas method accurately estimates volume of irregularly margined structures, especially when small slice thickness and interval are used.[24] Consistent use of 1 method of measurement is recommended.

Evaluation of thyroid tissue in cats by use of CT has many potential uses. Computed tomography of the thyroid gland may be useful for diagnosing hyperthyroidism in cats. In humans with hyperthyroidism, abnormal thyroid tissue is less dense than normal thyroid tissue and the gland is enlarged.[9] Computed tomography may be an alternative for those who do not have access to nuclear medicine facilities or for those who do not want to use ionizing radiation to detect hyperthyroidism. It is possible that more accurate ^{131}I dose calculations could be made by use of CT volume measurements. Presently, empirical dosing of ^{131}I is effective[22]; however, it is possible that the amount of ^{131}I could be decreased by use of more accurate thyroid volume measurements, leading to shorter radiation isolation periods.[25] Shorter radiation isolation periods would mean less separation of cats from their owners and increased throughput of cats receiving ^{131}I. Computed tomography of the thyroid gland may be useful for discriminating between thyroid hyperplasia and thyroid carcinoma in cats. It is important to remember that iodinated contrast medium hinders uptake of ^{99m}Tc pertechnetate and ^{131}I in humans.[7,26] One week after IV administration of iodinated contrast medium (iohexol), ^{131}I uptake is decreased 53.4% in the thyroid gland in humans.[26] Thyroid gland ^{131}I uptake returned to normal baseline values within a few weeks; however, this was evaluated in only 1 patient.[26] In euthyroid rats, thyroid gland uptake of ^{131}I returned to normal baseline values 15 days after administration of iohexol (300 mgI/kg).[27]

Measurements were made by use of precontrast medium–enhanced images. In clinically normal cats, thyroid tissue is easily seen on precontrast images.[13] The greatest potential use for CT of the cervical area is evaluation of thyroid glands in hyperthyroid cats. Use of contrast medium would delay the start of ^{131}I treatment or thyroid scintigraphy because of potential suppression of ^{131}I uptake and ^{99m}Tc pertechnetate uptake immediately after iohexol injection.[7,26,27] After IV administration of iohexol to dogs, renal volume increased.[28] Similar changes may occur in thyroid glands in cats, suggesting that measurements obtained by use of precontrast medium–enhanced images are more accurate than those obtained by postcontrast medium–enhanced images. By use of postcontrast medium–enhanced images, the blood vessels adjacent to the thyroid glands were delineated.[13] The contrast medium–laden blood vessels were hyperattenuating, compared with the thyroid lobes.[13] Postcontrast medium–enhanced images are useful for evaluation of adjacent lymph nodes in humans with thyroid carcinomas.[7,29] Omission of postcontrast medium–enhanced CT images of thyroid glands in cats would decrease imaging time and may permit modification of the anesthesia protocol for CT imaging of thyroid glands.[13]

Our study had a few limitations. The number of cats used in this study was small. Each cat had histologically normal thyroid tissue, and serum thyroxine concentrations were within reference ranges. Comparing CT measurements to in situ measurements obtained by use of calipers would have been optimal. We attempted to measure each thyroid lobe and determine the volume of each lobe by use of water displacement after a month of neutral-buffered 10% formalin fixation. However, because it was not possible to accurately determine which dimension was height versus width or determine which lobe was left or right, we chose not to include this information.

We acknowledge that ultrasonography of thyroid glands in cats has several advantages, compared with CT imaging. By use of ultrasonography, general anesthesia is not required and cats do not receive ionizing radiation. Ultrasound machines are more available than CT scanners. Acquiring CT images of thyroid glands is less user dependent than using ultrasonography, offering a potential advantage for CT versus ultrasonography. Our rationale for performing the study reported here was not to find a better method than ultrasonography for evaluating thyroid glands in cats, but to establish CT dimensions and volume of thyroid glands in clinically normal cats for further investigation.

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