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COMPUTED TOMOGRAPHIC, ULTRASONOGRAPHIC AND RADIOGRAPHIC FEATURES OF CAPRINE CONGENITAL GOITER AND NORMAL THYROID GLAND IN 2-MONTH-OLD GOATS

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Abstract. Goiter, that is enlargement of the thyroid gland, is one of the most common symptoms of thyroid disease in goats. It is usually caused by an iodine deficiency in the diet or the consumption of goitrogenic substances, less often by genetic factors. The development of diagnostic imaging in veterinary medicine and the increasing tendency of animal owners to perform imaging examinations create the need to describe diseases and normal organs in these examinations. The aim of the study was to present the ultrasonographic (US), computed tomographic (CT) and radiographic features of the congenital goiter and the normal thyroid gland in 2-month-old goats. The study was conducted on 18 female goats. Basic diagnostic imaging features of the thyroid gland, such as size, shape, echogenicity, echostructure and density were described. The thyroid gland with congenital goiter showed heterogeneous echostructure and reduced or normal echogenicity on US, reduced density on CT and soft tissue enlargement in the cranial neck area on radiography. Normal thyroid gland in 2-month-old goats on US had mean dimensions of 16 mm × 7 mm × 3.8 mm, homogeneous echostructure and echogenicity higher than the surrounding muscles. On CT, it had mean dimensions of 16.4 mm × 7.7 mm × 4.6 mm and mean density of 80.5 Hounsfield units (HU), while on radiography it couldn't be differentiated from the surrounding soft tissues. US and CT enable visualization of the thyroid gland and can be used to diagnose congenital goiter in goats. The results of this study contribute to the knowledge of diagnostic imaging of the caprine thyroid gland.

Key words: congenital goiter, thyroid gland, goats, caprine, ultrasonography, computed tomography.

INTRODUCTION

One of the most common symptoms of thyroid disease in goats is an enlarged thyroid gland, called goiter. The cause of the disease is usually nutritional abnormalities related to iodine deficiency in the diet or the consumption of goitrogenic substances, less often genetic factors causing defects in the enzymes responsible for the synthesis of thyroid hormones. It results in too low levels of triiodothyronine and thyroxine in the blood, which leads to an increased release of thyroid stimulating hormone, which in turn causes the enlargement of the thyroid gland (Bhardwaj 2018).

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Congenital goiter is a form of the disease and is caused by maternal nutritional errors or genetic factors. The most frequent clinical signs are late-term abortions, stillbirths, or death shortly after birth. Affected goat kids have an enlarged thyroid gland on both sides and may show other symptoms, such as alopecia, prognathism or dyspnea (Ozmen et al. 2005).

The diagnosis of thyroid disorders is made primarily by clinical examination and laboratory findings. When a straightforward diagnosis of the thyroid disease on the basis of these examinations is impossible, diagnostic imaging may be helpful. Thymus enlargement, abscess, cyst or enlarged lymph nodes can also cause swelling in the neck and make it difficult to determine the origin of the lesion (Smith and Sherman 2009).

In goats, the thyroid gland consists two lobes located just caudal to the larynx and lateral to the trachea. The lobes may be oval, ellipsoidal or almond-shaped and are connected by poorly developed, fibrous isthmus. In studies by various authors, an adult goat's thyroid lobe has a mean length of 32 mm, mean width of 12.6 mm and mean height of 6.8 mm and weights 1.75–4.1 g. In 1-day-old goats, it is 11.4 ± 0.3 mm long, 5.2 ± 0.1 mm wide, 3.7 ± 0.1 mm high and weights 0.13 ± 0.0 g, while in 10-month-old goats, it is 23.5 ± 0.3 mm long, 13.9 ± 0.1 mm wide, 8.1 ± 0.2 mm high and weights 1.21 ± 0.02 g (Sanjeev and Rakesh 2015; Sarma et al. 2017; Pankowski et al. 2020).

The thyroid gland in adult goats is perfectly visible on US and CT, which is consistent with studies in humans, dogs and cats (Pankowski et al. 2021). Due to the increasing availability and decreasing cost of imaging examinations and the increasing tendency of animal owners to perform them, these methods can now be used to diagnose lesions in the neck area also in goats. According to the authors' best knowledge, so far there are no studies describing the ultrasonographic together with computed tomographic image of the congenital goiter in goats and also normal thyroid gland in 2-month-old goats.

In humans, diagnostic imaging is widely used in diseases of the thyroid gland. In clinical practice, especially US and scintigraphy and less often CT or magnetic resonance imaging are performed. Ultrasonography is useful for the assessment and monitoring of thyroid nodules and ultrasound-guided thyroid biopsy, while CT is primarily used to assess the extent of the neoplastic process, its invasion into the surrounding structures and lymph nodes and for preoperative planning (Nachiappan et al. 2014; Saeedan et al. 2016; Blum 2020).

The aim of the study was to present the ultrasonographic, computed tomographic and radiographic features of the congenital goiter and the normal thyroid gland in 2-month-old goats.

MATERIAL AND METHODS

Eighteen goats were used in the research. Nine of them had congenital goiter, while the remaining 9 had normal thyroid gland and made up a control group. Animals with goiter were stillborn or died shortly after birth. Goats without goiter were 2-months-old and belonged to the Polish White Improved breed. All animals were female. Individuals with goiter were obtained from households, where the animals were kept for private use, while the control group was taken from a large dairy herd after it was intended for culling due to the clinical form of caprine arthritis-encephalitis, confirmed by the ELISA test (ID Screen MVV / CAEV Indirect Screening test, ID.vet; Innovative Diagnostics, Grabels, France). The animals were euthanized by intravenous administration of pentobarbital (Morbital, Biowet Puławy, Poland) at a dose of 30 mg/kg, preceded by induction of general anesthesia with a mixture of xylazine (Xylapan, Vetoquinol, Poland) at a dose of 0.05 mg/kg and ketamine (VetAgroam, Poland) at a dose of 10 mg/kg.

Ultrasonographic, CT, radiographic and post-mortem examinations were performed in all animals. In animals with congenital goiter, these were performed as soon as possible after stillbirth or death, while in goats without goiter immediately after euthanasia.

Ultrasound was performed in B-mode on the animals lying on their side with the head and neck extended. Before the ultrasound examination, the hair from the neck area was clipped and copious amounts of alcohol and ultrasound gel were applied. An ultrasound scanner (HM70A, Samsung Electronics Ltd., UK) with a linear probe with a frequency of up to 13 MHz was used. The thyroid lobes were located, their echostructure, shape, margins and echogenicity in relation to the surrounding muscles were assessed. The maximum length in the longitudinal axis and the maximum width and height in the transverse axis of the lobe were measured.

Radiographic examination was performed using direct computed radiography system. An X-ray images were taken in lateral and ventro-dorsal projection with the head extended and with the central beam directed towards the laryngeal area, using the exposure parameters of 50 kV and 10 mAs.

The CT scan was performed on animals in lateral recumbency, using a 16-row scanner (Philips & Neusoft Medical Systems) with the parameters 120 kV, 150 mA, slice thickness 0.75 mm and with reconstruction in the soft tissue algorithm. The area from the cranial part of the larynx to the thoracic inlet was scanned. A DICOM reader was used to analyze computed tomography images (Horos, Nimble Co LLC d/b/a Purview, Annapolis, MD, USA, version 4.0.0). The computed tomographic features of the gland, such as shape, location, structure, margins and density were assessed in multiplanar reconstruction. The maximum length of the lobe was measured in its longitudinal axis, while the maximum width and height in its transverse axis. The density of the gland was measured by placing a region of interest (ROI) of 1 mm^2 in the central part of the lobe.

Post-mortem examination was carried out in a routine manner immediately after the imaging examinations. The thyroid gland was dissected, removed and measured with an electronic caliper (TESA CAL IP67, accuracy 0.01 mm) and weighed with an electronic balance (Axis AD2000, accuracy 0.01 g).

RESULTS

On the US examination of goats with congenital goiter, the thyroid gland was enlarged, rounded, with mainly smooth, sometimes irregular margins, with a heterogeneous echostructure of the parenchyma. The echogenicity of the parenchyma was reduced and similar to that of the surrounding muscles in 4 goats, and in other 5 goats clearly higher than that of the surrounding muscles (Fig. 1). The enlarged glandular isthmus with echogenicity and echostructure similar to that of the thyroid lobes that it connected was visible. Size measurements, especially the length of the lobe, were difficult to obtain, because the lobe was bigger than the scanning area of the probe. This required the probe to be moved to visualize the entire gland.

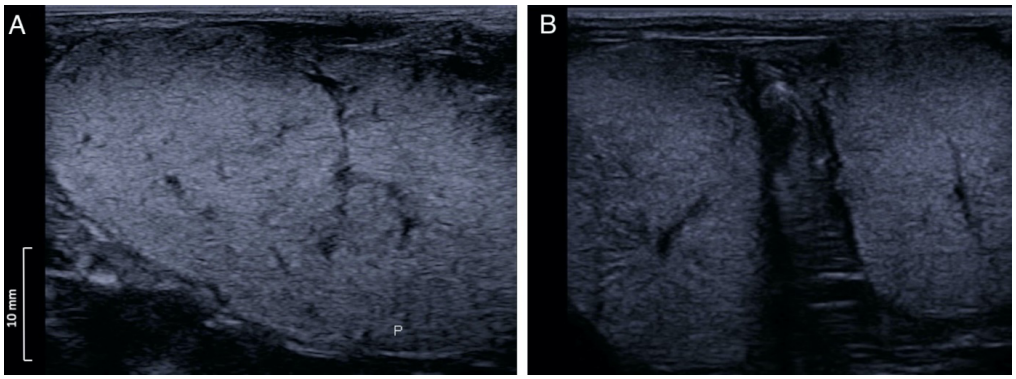

Fig. 1. Ultrasound image of the thyroid lobe with congenital goiter in the longitudinal (A) and transverse (B) axis. The lobe is enlarged, rounded, with heterogeneous echostructure and echogenicity higher than that of the surrounding muscles

CT examination of goats with congenital goiter showed enlarged and rounded thyroid gland with a homogeneous and reduced density, similar to the surrounding muscles. The mean density was 52 ± 17.7 Hounsfield units. The margins of the lobes were clearly visible and precise measurements of the length, width and height of the lobe were possible (Fig. 2).

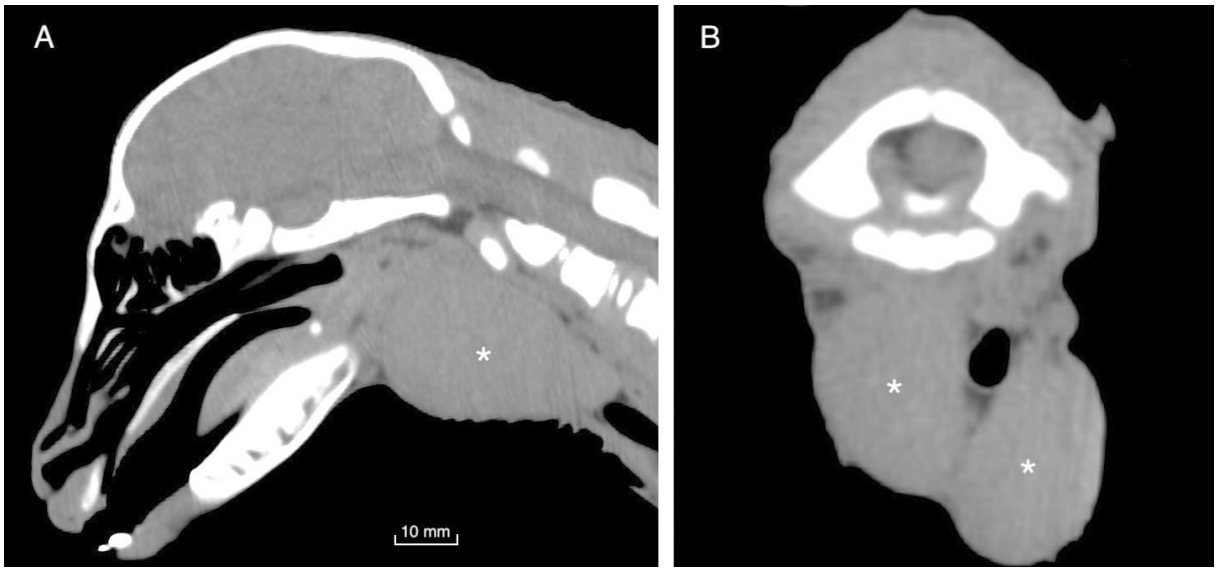

Fig. 2. Computed tomography image of the thyroid gland with goiter in sagittal reconstruction (A) and in the transverse plane (B). The lobes are enlarged, rounded, with reduced density, similar to that of the surrounding muscles. The margins of the lobes are clearly visible. The thyroid lobe is marked with an asterisk

Radiographic examination in goats with congenital goiter showed a symmetrical soft tissue enlargement in the cranial part of the neck. The attenuation was uniform, with soft tissue opacity, without the possibility to unequivocally identify the origin of the lesion (Fig. 3).

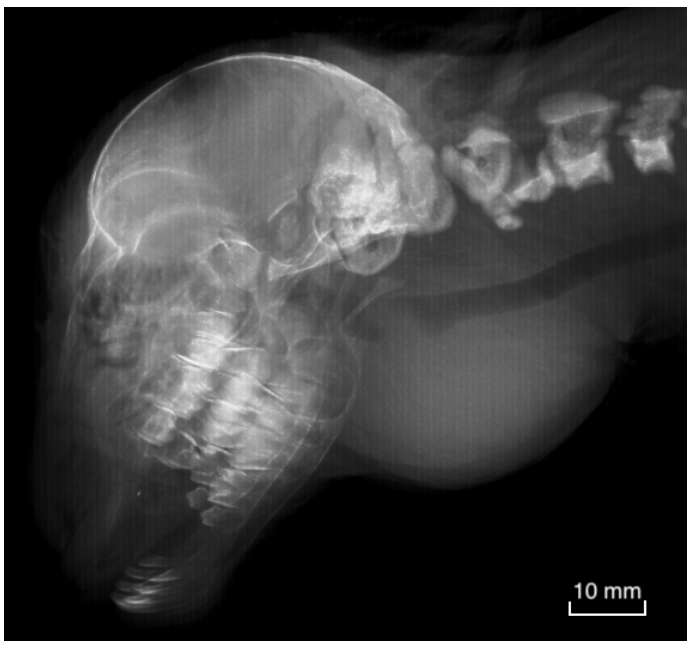

Fig. 3. An X-ray image in the lateral projection of a goat with congenital goiter. A soft tissue enlargement is visible in the cranial part of the neck. Radiography does not allow for clear Identification of the origin of the lesion

On the US examination of the control group, the thyroid gland was oval to ellipsoidal in longitudinal axis and oval in transverse plane, with smooth margins, homogeneous echostructure and echogenicity higher than that of the surrounding muscles (Fig. 4). An isthmus was not visible. The mean dimensions of the thyroid lobe were 16 ± 1.8 mm in length, 7 ± 1.1 mm in width and 3.8 ± 0.6 mm in height.

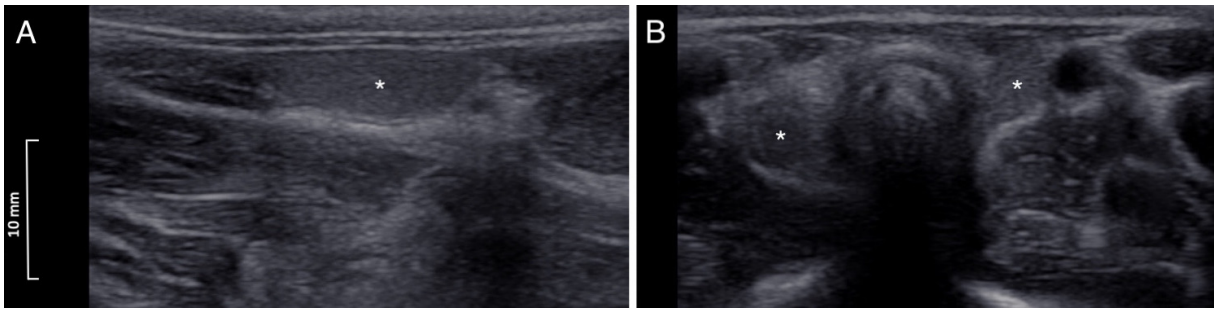

Fig. 4. Ultrasound image of the normal thyroid gland in a 2-month-old goat in sagittal (A) and transverse (B) axis. The lobes are normal in size, with smooth margins, with a homogeneous echostructure and uniform echogenicity, higher than that of the surrounding muscles. The thyroid lobes are marked with an asterisk

CT examination of the control group showed thyroid gland that was normal in size, ellipsoid-shaped, homogeneous and hyperdense in relation to the surrounding soft tissues. Its mean density was 80.5 ± 16.6 HU (Fig. 5). The mean dimensions of the thyroid lobe were 16.4 ± 2.1 mm in length, 7.7 ± 0.8 mm in width, and 4.6 ± 0.5 mm in height.

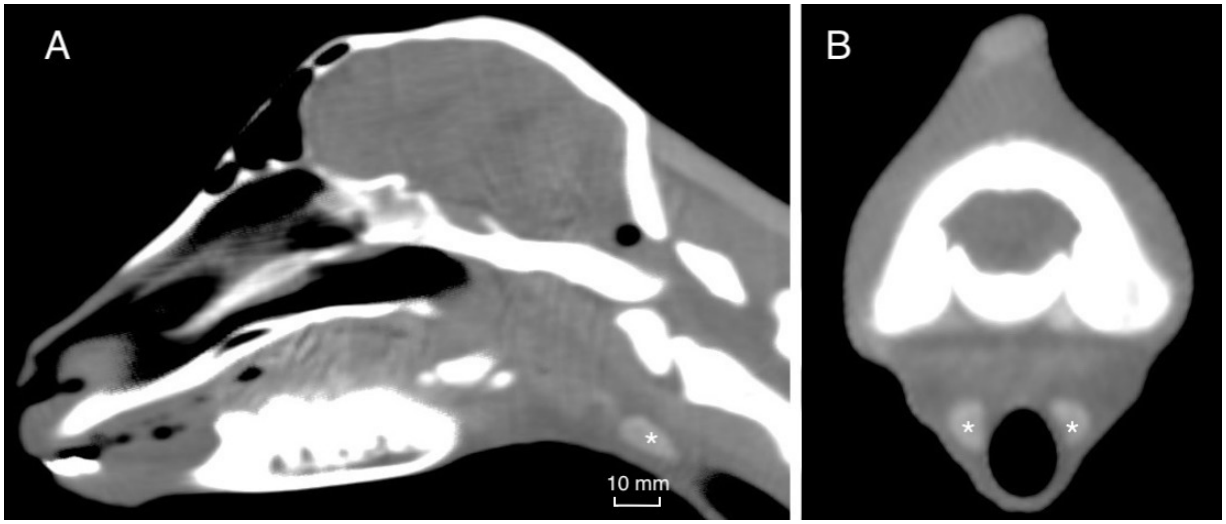

Fig. 5. Computed tomography image of the normal thyroid gland in a 2-month-old goat in sagittal reconstruction (A) and in the transverse plane (B). The lobes are of normal size, typical ellipsoid shape and uniformly hyperdense compared to surrounding soft tissues. The margins of the lobes are perfectly visible. The thyroid lobes are marked with an asterisk

On radiographic examination of the control group, the thyroid gland was not visible, indistinguishable from the soft tissues of the neck.

Post-mortem examination of goats with congenital goiter showed massive symmetrical subcutaneous deformations in the cranial part of the neck (Fig. 6). The thyroid lobes were 42–53 mm long, 27–41 mm wide and 17–30 mm high. The lobes weighted 11–35 g. An enlarged isthmus was visible, which was 16–23 mm long, 12–18 mm wide and weighted 1.2–2.2 g.

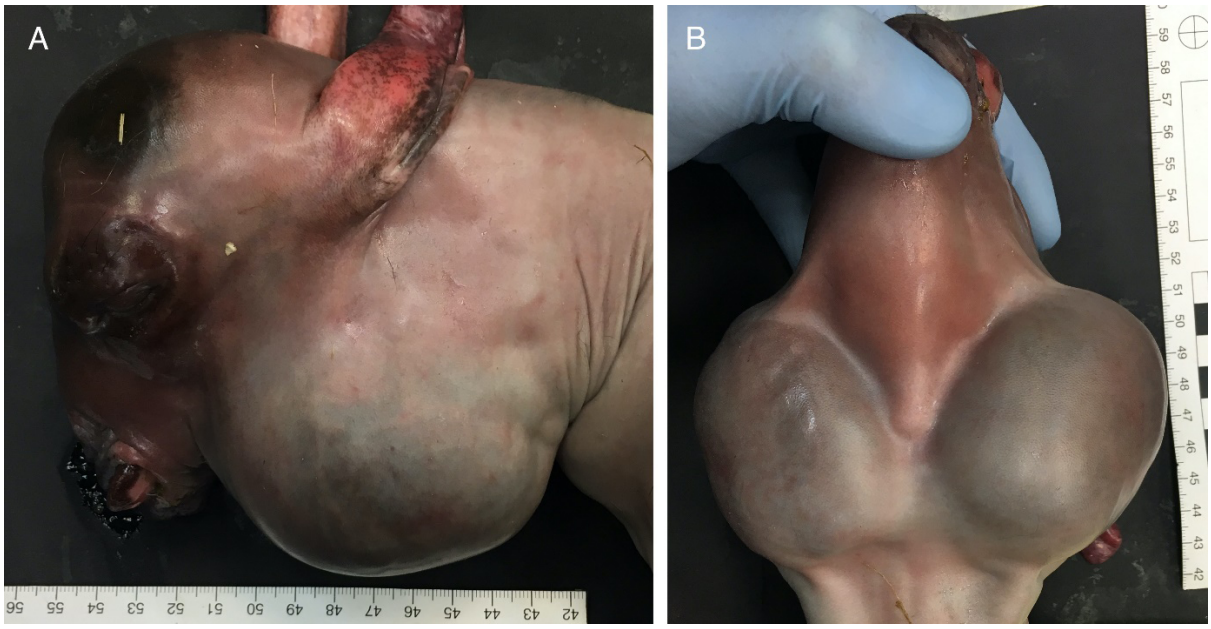

Fig. 6. Post-mortem images of goats with congenital goiter. Massive subcutaneous deformations are visible in the cranial part of the neck. Alopecia of the whole body is noticeable

On post-mortem examination of the control group, the thyroid gland was normal in size. The mean dimensions of the lobe were 16.7 ± 1.6 mm in length, 7.8 ± 1.2 mm in width and 5 mm ± 0.9 mm in height and the mean weight was 0.39 ± 0.1 g.

DISCUSSION

To the best of the authors' knowledge, this is the first comprehensive study showing computed tomographic, ultrasonographic and radiographic characteristics of the congenital goitre and normal thyroid gland in 2-month-old goats.

So far, a case-series of 3 goats with congenital goitre has been described, in which an ultrasound examination was performed to confirm the thyroid origin of the lesion in the neck area (Davoodi et al. 2022). The examination showed enlarged, well-defined lobes with heterogeneous echostructure and higher echogenicity in relation to the surrounding tissues. This is partially consistent with current study, as in all nine goats with goiter, the echostructure of the gland was heterogeneous, while four out of nine animals had thyroid echogenicity similar to that of the surrounding muscles, instead of higher.

In the ultrasound examination, the echogenicity of the thyroid lobes is compared to the echogenicity of the adjacent muscles of the neck and it is normally higher. In dogs, the decrease in echogenicity with reduction of the thyroid gland size indicate hypothyroidism, while the decrease in echogenicity with enlarged thyroid gland may indicate a neoplastic process (Reese et al. 2005; Taeymans et al. 2013). In cats, on the other hand, the most common thyroid disease is hyperthyroidism, in which the lobe is enlarged with heterogeneous echostructure and often decreased echogenicity (Barberet et al. 2010). In the current study, thyroid echogenicity in congenital goiter was reduced or normal, indicating that echogenicity by itself cannot be used to determine thyroid hormone status, and that the echogenicity is not always decreased in caprine hypothyroidism.

Accuracy of the thyroid measurements on ultrasound, as in any other diagnostic imaging modality, depend on the person performing the examination. Determining the volume of the gland by using the ellipsoid formula, based on the measurement of the maximum length, width

and height of the lobe, has an average error of about 15% and most often underestimates the actual size of the organ (Vurdem et al. 2012; Viduetsky and Herrejon 2019). In the current study, the measurements of goiter size on ultrasound, especially the length, were burdened with an additional error. The lobes were often bigger than the maximal scanning area of the probe, therefore it was not possible to make a measurement without moving the probe to visualize the rest of the organ. Radiography on the other hand, could not reliably distinguish the thyroid gland from soft tissues of the neck, therefore it can't be used for accurate measurements. A CT scan is definitely the best choice when the most precise measurements are desired, because it visualizes the entire organ with determination of its margins, and with the use of multiplanar reconstruction, it enables actual measurements to be made.

Normal thyroid gland in adult goats, dogs, cats and humans is hyperdense in relation to the surrounding muscles on a CT scan performed without intravenous contrast administration. This is due to the high content of iodine and thus greater attenuation of X-rays by the thyroid gland (Drost et al. 2004; Saeedan et al. 2016; Amorós et al. 2021; Pankowski et al. 2021). The same was observed in the control group of 2-month-old goats in the present study. In humans, decreased density of the thyroid gland is related to its malfunction and may indicate diffuse pathological changes of the thyroid gland (Maldjian and Chen 2016). Thyroid density in all goats with congenital goiter was clearly reduced, which corresponds to the state of hypothyroidism related to this disease.

Radiographic examination alone does not allow to accurately diagnose the organ from which the lesion on the neck originates. Some pathological changes visible on X-ray, such as soft tissue enlargement, suggest that the thyroid gland is affected, but only an ultrasound or CT scan is conclusive. This is consistent with the observations of Vilaplana Grosso et al. (2020), in whom the changes found on X-ray raised the suspicion of a pathological process in the retropharyngeal area, but only CT examination made it possible to diagnose enlarged lymph node in the course of caprine caseous lymphadenitis.

The conducted study has some limitations. Goats from the control group had clinical form of caprine arthritis-encephalitis. This chronic disease most often causes lesions in the joints, central nervous system, lungs, udder, less often kidneys and the heart (Murphy et al. 2021). The authors are not aware of any publications or other sources that would confirm the impact of this disease on the morphology or function of the thyroid gland, therefore the gland was treated as normal. In addition, the study was performed on cadavers, therefore it was not possible to assess the thyroid vascularization by doppler ultrasound or to use an intravenous iodine contrast agent in the CT scan. Further studies are needed to establish the pattern of thyroid vascularization in the course of congenital goiter and to see how the thyroid density changes after administration of a contrast agent.

RECAPITULATION

For the first time, a comprehensive picture of US, CT and radiographic features of congenital goiter in goats was presented. US and CT can be successfully used to diagnose congenital goiter in goats. Additionally, the normal US and CT characteristics and dimensions of the thyroid gland in 2-month-old goats were presented. This adds to the knowledge of diagnostic imaging of the thyroid gland in this species.

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CHARAKTERYSTYKA WRODZONEGO WOLA TARCZYCY ORAZ PRAWIDŁOWEJ TARCZYCY U 2-MIESIĘCZNYCH KÓZ W BADANIU TOMOGRAFII KOMPUTEROWEJ, ULTRASONOGRAFICZNYM I RADIOGRAFICZNYM

Streszczenie. Wole, czyli powiększenie tarczycy, jest jednym z najczęściej występujących objawów choroby tarczycy u kóz. Zazwyczaj spowodowane jest niedoborem jodu w diecie lub spożywaniem substancji goitrogennych, rzadziej czynnikami genetycznymi. Rozwój diagnostyki obrazowej w weterynarii i coraz większa skłonność właścicieli zwierząt do wykonywania badań obrazowych stwarza potrzebę opisywania chorób oraz prawidłowych narządów w badaniach radiologicznych. Celem badania było przedstawienie cech ultrasonograficznych (USG), tomografii komputerowej (TK) oraz radiologicznych (RTG) wrodzonego wola tarczycy oraz prawidłowej tarczycy u 2-miesięcznych kóz. Badanie zostało przeprowadzone na 18 kozach płci żeńskiej. Opisano podstawowe cechy radiologiczne, takie jak rozmiar, kształt, echogeniczność, echostruktura i densyjność tarczycy. Tarczyca w przebiegu wrodzonego wola w badaniu USG miała niejednorodną echostrukturę i obniżoną lub prawidłową echogeniczność, w badaniu TK obniżoną densyjność, natomiast w badaniu RTG powodowała powiększenie obrysu tkanek miękkich w rejonie szyi. Tarczyca prawidłowa u 2-miesięcznych kózek w badaniu USG miała średnie wymiary 16 mm × 7 mm × 3,8 mm, jednorodną echostrukturę i echogeniczność wyższą niż okoliczne mięśnie. W badaniu TK miała średnie wymiary 16,4 mm × 7,7 mm × 4,6 mm oraz średnią densyjność 80,5 jednostek Hounsfielda, natomiast w badaniu RTG była niewidoczna. Ultrasonografia i tomografia komputerowa umożliwiają zobrazowanie tarczycy u kóz i mogą być wykorzystywane do rozpoznawania wrodzonego wola. Wyniki tego badania wzbogacają wiedzę z zakresu diagnostyki obrazowej tarczycy u kóz.

Słowa kluczowe: wrodzone wole, tarczyca, kozy, ultrasonografia, tomografia komputerowa.