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1. Title Page:

- **Title:** Thyroid gland computed tomography attenuation variability and correlation with total T4 and TSH values in brachycephalic and non-brachycephalic dogs
- **Key words:** Hounsfield units, hypoattenuating, TT4, TSH, canine
- **Conflict of interest disclosure:** The authors do not have any conflict of interest.
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- **EQUATOR network disclosure:** Any EQUATOR network checklist was used.

2. Abstract:

Computed tomography (CT) has been used in human medicine to evaluate the functional status of the thyroid gland by means of Hounsfield units (HU). In veterinary medicine, studies describing canine attenuation value abnormalities, other than those in thyroid neoplasm, are lacking. Anecdotally, the authors had observed subjective reduction of the thyroid attenuation values in some brachycephalic dogs. In order to determine the thyroid gland attenuation variability on CT and its correlation with thyroid hormone levels, an analytical cross-sectional study, combining prospective and retrospective parts was performed. The thyroid attenuation values of 53 owned dogs were assessed using a 16-slice helical CT scanner. Differences in attenuation between brachycephalic and non-brachycephalic dogs were estimated by Welch's t-test. Additionally, serum TT4 and TSH levels were evaluated in 30 patients. Statistically significant differences were observed in the pre-contrast attenuation value ranges between brachycephalic and non-brachycephalic dogs ($p=0.04$). No statistically significant differences were observed in the post-contrast

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3 25 attenuation values between breeds ($p=0.5$). The pre-contrast value range for the
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5 26 brachycephalic group was 69.1 – 108 HU while it was 75.8-121 HU for the non-
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7 27 brachycephalic group. No significant correlation was found between thyroid attenuation and
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9 28 serum thyroid hormone levels ($p>0.6$). All patients with hypoattenuating thyroid gland were
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11 29 brachycephalic and had normal thyroid hormone levels. Thus, brachycephalic dogs seem to
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13 30 have a pre-contrast attenuation thyroid gland range lower than non-brachycephalic dogs.
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15 31 Additionally, variations in the pre-contrast attenuation values of an otherwise normal-
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17 32 appearing thyroid gland in CT does not seem to be associated with alterations of the thyroid
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19 33 function.
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35 **3. Text:**

36 1. INTRODUCTION

37 The normal canine thyroid gland is composed by two flattened ellipsoid lobes that lie
38 adjacent and dorsolateral to the cranial segment of the cervical trachea.^{1,2} The primary
39 function of the thyroid gland is the synthesis of hormones with a vital role in the regulation of
40 multiple metabolic functions including cardiac output, lipid catabolism, skeletal growth, and
41 oxygen and heat production.³ The thyroid gland has been described on unenhanced computed
42 tomography (CT) as a hyperattenuating structure relative to the surrounding soft tissues due
43 to its high iodine concentration.^{1,2,4,5} The attenuation value ranges for both pre- and post
44 contrast series have been reported to be approximately 87 – 137 and 125 – 230 HU,
45 respectively.¹ In thyroid disorders, abnormalities in iodine metabolism can cause differences
46 in the iodine content of the gland.⁶ In human medicine, it has been described that CT
47 attenuation values allow estimation of the functional status of the gland, with lower
48 attenuation in diseases such as thyroiditis, hypothyroidism, hyperthyroidism or thyroid
49 tumors.^{6,7,8,9} In veterinary medicine, Hounsfield units have been extensively used to

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3 50 characterise lesions as they can provide malignancy or benignity criteria in organs such as the
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5 51 liver¹⁰ or the spleen.^{11,12}
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8 52 Computed tomography is recommended in dogs as a screening tool, preoperative diagnosis
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10 53 and staging for thyroid masses.⁸ Dogs with thyroid carcinoma were reported to have thyroid
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12 54 gland attenuation values much lower than those with normal thyroid tissue.⁸ Even though the
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14 55 thyroid gland is included in all cervical CT scans, there is lack of studies describing canine
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16 56 attenuation value abnormalities, other than those in thyroid neoplasm.
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18
19 57 Hypothyroidism is the most common thyroid disease and one of the most common endocrine
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21 58 disorders in dogs. Due to the variability of clinical signs and the limitations of thyroid tests it
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23 59 is frequently misdiagnosed.¹³
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26 60 Anecdotally, the authors had observed a subjective reduction of the thyroid attenuation in
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28 61 some patients undergoing CT for reasons not related to thyroid disease, this fact being
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30 62 possibly more frequent in brachycephalic dogs. The hypothesis of the authors were that
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32 63 thyroid CT attenuating values may correlate with thyroid gland function and that CT may be
33
34 64 helpful for diagnosing pathologies such as hypothyroidism. Moreover, the authors
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36 65 hypothesized that the attenuation values for brachycephalic thyroid gland could be lower than
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38 66 those for non-brachycephalic dogs. The aims of the present study were trifold: firstly, to
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40 67 determine a normal reference range for CT thyroid attenuation values of our study
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42 68 population; secondly, to correlate a quantified value of attenuation by HU with values of total
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44 69 thyroxine (TT4) and thyroid stimulating hormone (TSH) in dogs; and finally, to determine if
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46 70 there was a significant difference between thyroid gland attenuation values in brachycephalic
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48 71 and non-brachycephalic dogs.
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55 73 2. MATERIALS AND METHODS

56 74 2.1 Study design

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3 75 This is an analytical cross-sectional study and comprises a prospective and a retrospective
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5 76 part. The retrospective study was design to determine a normal reference range for CT
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7 77 thyroid attenuation values of the study population. The prospective study was design to
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9 78 correlate a quantified value of thyroid attenuation by HU with serum values of TT4 and TSH
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11 79 hormones.

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14 80 Images from dogs that underwent a CT study including the cervical region between January
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16 81 2016 and September 2019 were reviewed. Additionally, serum TT4 and TSH were tested in
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18 82 those dogs that underwent a CT study including the cervical region between January 2019
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20 83 and September 2019. For all dogs, the only eligible criterion was the inclusion of the thyroid
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22 84 region in the scans. The exclusion criteria were dogs receiving any administration of
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24 85 iodinated contrast material on the previous 8 weeks, lack of data on their medical reports,
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26 86 presence of heterogeneous thyroid glands with nodules or cystic lesions, and dogs under
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28 87 medication that have been described to alter the thyroid function such as glucocorticoids,
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30 88 phenobarbital, sucralfate, furosemide, or sulphonamides.⁴ The decisions for subject inclusion
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32 89 were made by the first author, a diagnostic imaging intern, after agreement with an ECVDI-
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34 90 board certified veterinary radiologist and a senior radiology professor. Information
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36 91 summarized from the medical records including signalment (age, breed, sex, neuter status,
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38 92 body weight), presenting complaint, administered medications, clinical history, physical
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40 93 examination findings, complete blood count (CBC), and serum biochemical profile was
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42 94 available. The study population was sub-classified in brachycephalic and non-brachycephalic
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44 95 dogs to assess if there were differences in the thyroid attenuation values between both groups.
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46 96 In aim to assess if the presenting complaint or the medications employed (other than those
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48 97 already used as exclusion criteria) in the study population could have influenced the
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50 98 attenuation value results, a control group was established. All dogs with normal CBC and
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52 99 serum biochemical profile, under no medication and with non-systemic pathologies unrelated
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3 100 to the thyroid gland were included in the control group.
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7 8 102 **2.2 Imaging procedure**

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10 103 Dogs underwent cervical CT scans in ventral, dorsal or lateral recumbence, depending on the
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12 104 region of interest and clinical condition. Images were acquired in soft tissue, bone and/or
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14 105 lung algorithms. Dogs were under general anaesthesia using a mixture of oxygen and
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16 106 isoflurane (Abbott Laboratories, Madrid). Scans were performed in a 16-slice helical CT
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18 107 scanner (General Electric Brivo CT 385) with a slice thickness of 0.625 mm or 1.25mm,
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20 108 interval thickness of 0.625 mm, collimation pitch of 0.5625:1, 120 kV, 50–90mA, field of
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22 109 view according to patient size, and a matrix of 512 × 512. When needed, contrast medium
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24 110 was administered and images were acquired approximately 30 seconds after administration of
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26 111 2 mL/kg IV Iopamidol (Scanlux 300 mg/mL; Sanochemia Pharmazeutika, Vienna) in the
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28 112 cephalic vein manually or by injector. All data were transferred to a workstation and analysed
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30 113 using a medical image viewer (Centricity PACS-IW [GE Healthcare]).
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36 114 **2.3 Image analysis**

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38 115 Retrospective evaluation of canine cervical CT studies was performed independently by the
39
40 116 first author. Attenuation values of the thyroid gland were measured in Hounsfield units, using
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42 117 a circular/ovoid region of interest (ROI) following the same protocol previously described by
43
44 118 Taeymans et al.¹ in dogs for measurement of the normal thyroid gland attenuation values.
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46 119 Briefly, ROIs were manually drawn around each cross section of both thyroid lobes on both
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48 120 pre- and post- contrast series, on every transverse CT slice including thyroid gland in the soft
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50 121 tissue window. The first and last slices of each lobe were excluded from this calculation to
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52 122 avoid partial volume artefacts. The computer automatically calculated the mean HU values
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54 123 and the standard deviation (SD) of each ROI. The mean attenuation value of the gland for
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56 124 each patient used for statistical analysis was given by the mean of the mean attenuation
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3 125 values of each transverse section of both lobes. Hypoattenuating thyroid glands were defined
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5 126 as those with a mean attenuation thyroid value lower than the lower limit for the thyroid
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7 127 gland attenuation value range of our study population. Hyperttenuating thyroid glands were
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9 128 defined as those with a mean attenuation thyroid value greater than the upper limit for the
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11 129 thyroid gland attenuation value range of our study population. At the time of measurements,
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13 130 the first author was blinded to thyroid hormones results.
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18 131 **2.4 Blood test**

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20 132 Serum TT4 and TSH levels were measured in all dogs included in the prospective survey. To
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22 133 measure the serum thyroid hormone levels, venous blood via transdermal puncture was
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24 134 collected during the pre-anaesthetic blood tests. The blood samples were centrifuged at 3500
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26 135 rpm and plasma was kept in plastic tubes at -20°C as previously reported.^{1,14} All blood
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28 136 samples were assessed the same day to avoid daily fluctuations in laboratory results. Serum
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30 137 TT4 and TSH were determined by chemiluminescence assay. In this study, 16.7 to 37.3
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32 138 nmol/L and 0 to 0.64 nmol/L were respectively considered the reference ranges for TT4 and
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34 139 TSH serum levels.
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41 141 **2.5 Statistical analysis**

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43 142 All statistical tests were selected and performed by an external specialist, who had advanced
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45 143 training in research methods and statistics. The mean, SD and ranges were calculated with the
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47 144 version 3.6.1 of the statistical software R. The 'ggplot2' and 'ggpubr' packages were used for
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49 145 the data visualization. The range of "normality" for thyroid gland attenuation levels in CT
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51 146 was defined as the 5-95 quartiles of the distribution. The difference in attenuation levels (pre-
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53 147 and post-contrast values) between brachycephalic and non-brachycephalic dogs and control
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55 148 and non-control dogs were studied using Welch's t-test. The same model (Welch's t-test) was
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57 149 used to investigate the correlation between sex, presenting complaint and attenuation
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3 150 values. The relationship between medication and its effect on the attenuation was determined
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5 151 by a Welch Two-Sample T-test. The correlation between age and weight and attenuation
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7 152 values was investigated by exploring both linear and non-linear relationships. The same
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9 153 method was used to assess the correlation between TT4 and TSH serum hormones and the
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11 154 attenuation values. Linear relationships were discarded by checking their R-squared levels.
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13 155 Non-linear associations were discarded by checking the significance of the smooth terms of
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15 156 generalised additive models (GAM). For all tests, a P-value < 0.05 was considered
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17 157 significant.
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22 158 3. RESULTS

23 159 **3.1 Study population**

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27 160 One hundred and six owned dogs were recruited initially on the study including both
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29 161 prospective and retrospective parts. Forty-one dogs from the retrospective and none from the
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31 162 prospective part were excluded. Finally, 65 dogs were included; 53 dogs formed the study
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33 163 population and 12 dogs were considered as control group. Represented breeds from the study
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35 164 population included crossbreed (n=12), French Bulldog (n=12), Labrador Retriever (n=3),
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37 165 two each of Golden Retriever, Chihuahua, Pug, Cavalier King Charles Spaniel, German
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39 166 Shepherd, Poodle, Doberman Pinscher, and one each of English Bulldog, Blood Hound, West
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41 167 Highland White Terrier, Rottweiler, Cane Corso, Miniature Schnauzer, English Cocker
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43 168 Spaniel, Border Collie, Spanish Breton, Welsh terrier, Newfoundland, and Bichon Maltese.
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45 169 Twenty-two females (14 spayed, 8 entire) and 31 males (16 neutered, 15 entire) were
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47 170 included. The mean body weight was 20.4 kg (range: 3.2 – 63 kg) and mean age was 7.2
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49 171 years (range 5 months – 14 years). Dogs underwent CT for a variety of reasons, including
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51 172 neoplastic disease non-affecting the thyroid gland or cervical region in 39.6% (21/53), local
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53 173 abscess or inflammation in 18.9% (10/53), upper respiratory tract disease in 15.1% (8/53),
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55 174 otitis in 15.1% (8/53), neurological disease in 9.4% (5/53) and congenital malformation in
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3 175 1.9% (1/53). Among all dogs, 41.5% (22/53) were under medication including non-steroidal
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5 176 anti-inflammatories in 17% (9/53), antibiotics in 13.2% (7/53), gastric protectants in 7.5%
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7 177 (4/53), analgesics in 5.7% (3/53), antiemetic's in 5.7% (3/53), cyclosporine in 3.7% (2/53),
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9 178 and insulin in 1.9% (1/53).

12 179 Dogs were divided into brachycephalic¹⁵ (n=20, including French Bulldog, English Bulldog,
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14 180 Pug, Chihuahua, Cavalier King Charles Spaniel and Cane Corso) and non-brachycephalic
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16 181 (n=33, including all other breeds). The mean age for the brachycephalic group was 7.5 years
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18 182 (range 5 months – 12 years). The mean age for the non-brachycephalic group was 7 years
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20 183 (range 5 months – 14 years).

23 184 The control group included 12 dogs with normal CBC and serum biochemical profile and
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25 185 under no medication. Represented breeds included crossbreed (n=4), French Bulldog (n=2),
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27 186 and one each of English Bulldog, Labrador Retriever, Golden Retriever, Beagle, Whippet and
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29 187 Chinese Crested dog. Four females (3 spayed, 1 entire) and 8 males (4 neutered, 4 entire)
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31 188 were included. The mean body weight was 19.6 kg (range: 6 – 42 kg) and mean age was 4.2
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33 189 years (range 1 – 10 years). Their presenting complaint was unrelated to the thyroid gland or
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35 190 a systemic disease and included acute spine neurological signs with disc herniation in 5 dogs,
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37 191 lameness with coronoid process disease in 4 dogs, mild inspiratory dyspnoea with elongated
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39 192 palate in 2 dogs and one dog with mild periodontal disease.
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194 **3.2 Attenuation values**

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49 195 The thyroid gland could easily be identified on both pre- and post-contrast images. All
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51 196 thyroid lobes were homogeneous. Post-contrast images were acquired in 47 of the 53 dogs.

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54 197 The attenuation value ranges for both pre- and post- contrast series of the control group were:
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56 198 76.9 – 99.5 and 148 – 158 HU, respectively.

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58 199 The attenuation value ranges for both pre- and post contrast series of the study population (53
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3 200 dogs) were: 71 – 118 and 132 – 207 HU, respectively. No statistical differences were
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5 201 observed between the study population and the control group regarding the pre- and post-
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7 202 contrast thyroid attenuation values ($p=0.217$ and $p=0.0584$, respectively). The respective
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9 203 attenuation value ranges pre- and post-contrast are presented in Table 1. Additionally, no
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11 204 significant correlations were observed between thyroid attenuation values and age, sex,
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13 205 weight, medication employed or presenting complaint within the study population ($p>0.05$).
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20 207 **(Table 1)**
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27 209 The attenuation value ranges for the brachycephalic group pre- and post contrast series were
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29 210 69.1 – 108 and 134 – 209 HU, respectively. The attenuation value ranges for non-
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31 211 brachycephalic group pre- and post contrast series were: 75.8 – 121 and 134 – 196 HU,
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33 212 respectively (Table 1). Statistically significant differences were observed in the pre-contrast
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35 213 attenuation value ranges between brachycephalic and non-brachycephalic dogs ($p=0.04$). No
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37 214 significant differences were noticed in the post-contrast series between these two
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39 215 subpopulations ($p=0.5$) (Figure 1).
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47 217 **(Figure 1)**
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53 219 Among all dogs, 11.3% (6/53) had pre-contrast mean attenuation values lower than the lower
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55 220 limit for the reference range reported here; lower than 71 HU. These dogs included 4 French
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57 221 bulldogs and one each of Cavalier King Charles Spaniel and Cane Corso. The lowest mean
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59 222 value was 55.5 HU reported in a French bulldog, with poorly differentiation between the
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3 223 thyroid glands and the surrounding soft tissue (Figure 2). Among them, 4 dogs were not
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5 224 under medication; one was under antibiotic, antiemetic and gastric protectants and one under
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8 225 gastric protectants. Among all dogs, 13.2% (7/53) had pre-contrast mean attenuation values
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10 226 greater than the upper limit for the reference range reported here; greater than 118 HU. These
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12 227 dogs included 4 crossbreed and one each of Miniature Schnauzer, Cocker Spaniel and Blood
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14 228 Hound. No brachycephalic dogs were observed in this group. The greatest mean value was
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16 229 141 HU reported in a Miniature Schnauzer. All but one (under analgesia) was not receiving
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19 230 medication.
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24 232 **(Figure 2)**
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29 235 **3.3 Thyroid hormones values**

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32 236 Serum TT4 and TSH were evaluated in 30 dogs included in the prospective assay. The values
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34 237 for TT4 ranged from 6.4 to 32.8 nmol/L. The values for TSH ranged from 0.1 to 0.88 nmol/L.
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36 238 Among dogs tested for thyroid hormones 96.7% (29/30) were euthyroid and 3.3% (1/30)
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38 239 resulted compatible with hypothyroidism, with increased TSH and decreased TT4 levels.
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40 240 None of them was hyperthyroid. The TT4 and TSH levels tested for dogs with
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42 241 hypoattenuating thyroid gland were within normal limits. The possible hypothyroid dog had
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44 242 an attenuation mean value in the upper limit for the reference range reported here (119 HU).
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49 243 No statistically significant correlations were observed between TT4, TSH and the attenuation
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51 244 values of the thyroid gland ($p(\text{TT4 pre- and post-contrast})= 0.693, 0.61$; $p(\text{TSH pre- and post}$
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53 245 $\text{contrast})= 0.669, 0.843$)).
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58 59 247 **4. DISCUSSION** 60

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3 248 In the present study the thyroid attenuation value ranges for brachycephalic and non-
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5 249 brachycephalic breeds were evaluated. A remarkable finding not previously reported before,
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8 250 was that the thyroid gland pre-contrast attenuation values resulted significantly lower in
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10 251 brachycephalic than in non-brachycephalic breeds. Interestingly, all dogs with
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12 252 hypoattenuating thyroid gland were brachycephalic. Thus, is most likely to find
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14 253 homogeneous hypoattenuating thyroid gland in brachycephalic than in non-brachycephalic
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17 254 dogs. Furthermore, brachycephalic dogs are rarely in the upper limit for the reference range
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19 255 reported here.

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21 256 The pre-contrast attenuation range of our study population (71-118 HU) is mildly lower than
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24 257 the previously reported in the literature.^{1,2} A previous study¹ that evaluated the normal CT
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26 258 density of the thyroid gland in 25 dogs included only one brachycephalic dog (Dogue de
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28 259 Bordeaux), so this may be one of the explanations for the decreased range reported here when
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30 260 taking into account all the study population. Moreover, differences in the pre-contrast
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33 261 attenuation range reported, in comparison to previous ones,^{1,2} could be due to some un-
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35 262 controlled variables such as alimentary iodine intake, tap water iodine concentration and
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37 263 geographic differences.¹

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39 264 The precise reason for the decreased CT attenuation values in brachycephalic breeds is
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41 265 uncertain. Low attenuation but homogeneous thyroid gland on CT, has been sporadically
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44 266 described in the human literature. In 2010, Han et al.¹⁶ evaluated the thyroid CT attenuation
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46 267 in combination with thyroid functional tests and positron-emission tomography (PET/CT).
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48 268 The CT attenuation reflects iodine concentration, whereas fluorine-18-FDG uptake reflects
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50 269 cellular glucose metabolism. Thyroid density on CT was found to be closely related to FDG
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53 270 uptake. Low CT density coupled with high FDG uptake suggesting that there was a certain
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55 271 change in the thyroid tissue composition. This change could be a replacement of thyroid by
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58 272 other hypermetabolic tissue components, such as follicular cells, inflammatory cells, or other
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3 273 stromal tissue components.¹⁶ It was suggested that diffusely increased FDG uptake in the
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5 274 thyroid could indicate thyroiditis, Graves disease, or a normal individual variation. It was
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8 275 hypothesized that a clinically normal thyroid gland may present inflammation or glandular
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10 276 hyperplasia to some degree.¹⁶ Nevertheless, in that study the thyroid status was not
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12 277 pathologically confirmed. In the present study, the authors suggest that the low density
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14 278 observed in the thyroid gland of some dogs could be due to an individual or breed variation
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16 279 or mild degree of glandular hyperplasia with clinically normal thyroid. Studies including
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18 280 thyroid histological changes in brachycephalic breeds are lacking in veterinary medicine and
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21 281 could be subject of further investigations.

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24 282 Contrarily to the pre-contrast values, the post-contrast thyroid attenuation values in our dogs
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26 283 did not differ depending on the breed. In addition, the post-contrast attenuation values of our
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28 284 study population were similar to the previously reported.¹

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30 285 No correlation was found between attenuation values and sex, age, or weight. These last two
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32 286 parameters had already been studied by Taeymans et al¹, presenting the same results. There is
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34 287 a growing list of medications known to adversely affect thyroid function or its result's
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36 288 interpretation.⁴ In the present study, the only drug used that has been object of discussion for
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38 289 affecting the thyroid gland function was non-steroidal anti-inflammatory drugs. In veterinary
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40 290 medicine, the effects on thyroid function in dogs of two different non-steroidal anti-
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42 291 inflammatory drugs (meloxicam and carprofen) were evaluated.¹⁷ They concluded that TT4,
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44 292 free thyroxine (free-T4), and TSH concentrations were not affected after two months of
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46 293 administration of those drugs.¹⁷ In support of those results, as no significant differences in the
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48 294 thyroid attenuation values were observed between our study population and the control
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50 295 group, it was thought that neither the medication employed nor the presenting complaint
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52 296 affected the results.

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58 297 In the present study all dogs but one was considered euthyroid, with TT4 and TSH values
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3 298 within the normal range, regardless of the attenuation values. Only one dog was found to be a
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5 299 possible hypothyroid and no hyperthyroid dogs were present. The presumed hypothyroid dog
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7 300 was an 8 year old Blood Hound and under no medication. Interestingly, the dog had
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9 301 hyperattenuating thyroid gland, with a non-contrast mean attenuation value in the upper limit
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11 302 for the reference range reported here (119 HU). The authors admit that it would be
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13 303 pretentious to draw conclusions based in a single case that fits with hypothyroidism. It cannot
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15 304 be ensured that taking more dogs suffering these diseases the results regarding attenuation
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17 305 values would be different. In the human's literature it has been described that hypothyroid
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19 306 patients can result in hypoattenuating thyroid glands.⁶⁻⁹ In this occasion, we failed to find a
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21 307 clear association between thyroid hormones levels and CT attenuation values. In veterinary
22
23 308 medicine the functionality of the thyroid gland by CT was evaluated in cats revealing
24
25 309 controversial results. In 2013, Lautenschlaeger et al.¹⁸ evaluated the CT thyroid attenuation
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27 310 values in twenty-five hyperthyroid cats concluding that the densities were significantly lower
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29 311 than the reported for normal cats. In 2016, Bush et al¹⁹ reported that the attenuation of the
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31 312 thyroid gland was similar in euthyroid and hyperthyroid cats, but that the attenuation
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33 313 decreased during methimazole treatment.

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35 314 Even though it has been described in several human studies^{5-7,9} that hypoattenuating thyroid
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37 315 glands were strongly associated with decreased thyroid function, the results of the present
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39 316 study showed that hypoattenuating thyroid gland in dogs may be found in animals with
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41 317 normal TT4 and TSH values. Thus, CT attenuation did not seem to be correlated with thyroid
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43 318 gland function in dogs.

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45 319 The present study has several limitations; first of all, part of the study is retrospective with a
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47 320 small sample size, particularly in the control group. Importantly, there was no histological
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49 321 analysis of the thyroid gland to confirm the cause of low CT attenuation. The fact that French
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51 322 Bulldog was one of the overrepresented breeds was not casual, as it predominates in the
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3 323 caseload of multiple services -including neurology, dermatology, oncology or surgery- in the
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5 324 veterinary hospital where the study was placed. A larger scale prospective and multicentric
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8 325 study is required to confirm and refine the correlation between the CT density of the thyroid
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10 326 gland and its functional status, as well as to define reference ranges of thyroid CT densities in
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12 327 subpopulations including other breeds. Nevertheless, as homogeneous hypoattenuating
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14 328 canine thyroid gland in CT were not reported before, it is unlikely this to be a common
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16 329 feature for other breeds. The fact that a substantial number of the study population were
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18 330 receiving medication and presenting multiple focal and systemic diseases is reflective of a
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20 331 normal veterinary caseload. For ethical reasons, the study was not performed with completely
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22 332 healthy dogs, and was decision of the clinicians together with the owners to undertake a CT.
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24
25 333 In conclusion, the present study shows that brachycephalic dogs seem to have a pre-contrast
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27 334 attenuation thyroid gland range lower than non-brachycephalic dogs. Furthermore, variations
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29 335 in the attenuation of an otherwise normal-appearing thyroid gland on pre-contrast CT was not
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31 336 associated with alterations in the thyroid function. This was a preliminary attempt to correlate
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33 337 CT thyroid gland attenuation values with serum thyroid hormones in dogs. Additional studies
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35 338 in hyperthyroid and hypothyroid dogs are needed to refine the correlation between the CT
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37 339 density of the thyroid gland and its functional status.
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45 341 **4. List of Author Contributions:** Described in the unblinded document.
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48 342 **5. Acknowledgments:**
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52 344 **6. References:**
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397 7. Tables

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	Attenuation range		Mean attenuation	
	pre- contrast	post-contrast	pre-contrast	post-contrast
Control group	76.9 – 99.5	148 – 158	88.3	153
Study population	71 – 118	132 – 207	92.5	165
Brachycephalic	69.1 – 108*	134 – 209	87	173
Non-brachycephalic	75.8 – 121*	134 – 196	95.2	161

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400 **Table 1** Attenuation value ranges and mean attenuation values pre- and post- contrast,

401 measured in HU in different groups.

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3 404 **8. Figure legends**

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6 406 **Figure 1** Box plot showing the differences in pre-contrast (NC) and post-contrast (WC)
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9 407 attenuation values (in HU) between brachycephalic and non-brachycephalic dogs.

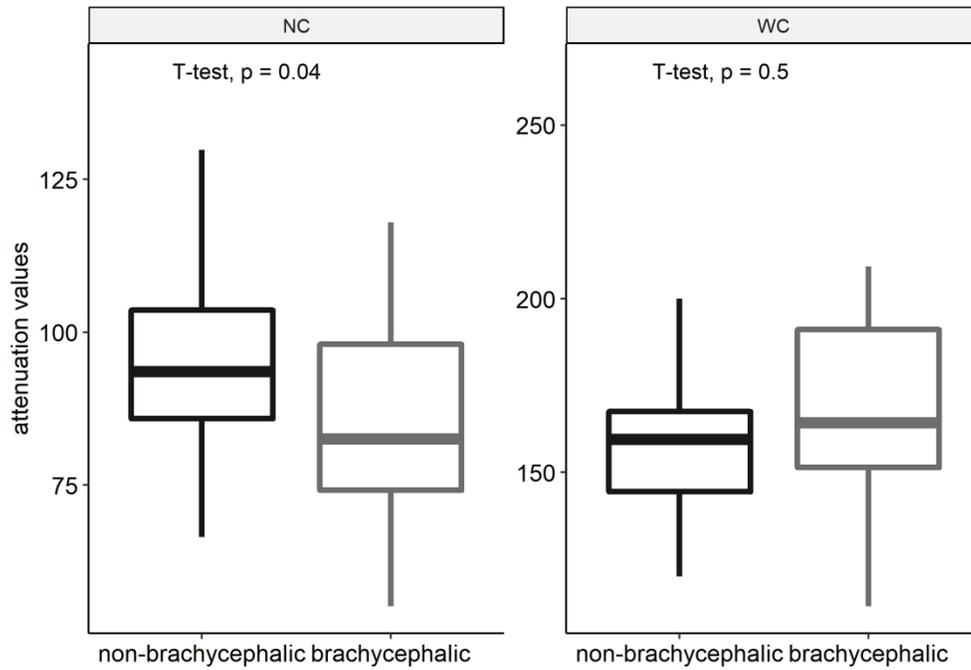
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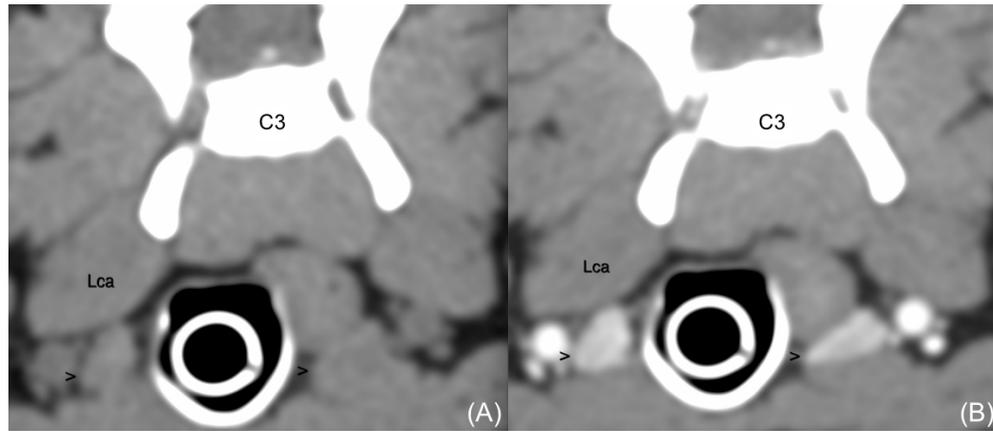
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3 410 **Figure 2** Example of CT transverse images in soft tissue algorithm, pre- (A) and post-
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5 411 contrast (B) of the cervical region of a brachycephalic dog. WL= 40; WW = 400. The slice
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7 412 location is at the middle aspect of the thyroid gland (black arrowheads), ventral to the third
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9 413 cervical vertebrae (C3). The thyroid gland in the pre-contrast series is isoattenuating to the
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11 414 *longus capitis muscle* (Lca) located dorsally to the gland. WW, window width; WL, window
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13 415 level.
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22 418 **9. Appendix:** No additional material.
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Box plot showing the differences in pre-contrast (NC) and post-contrast (WC) attenuation values (in HU) between brachycephalic and non-brachycephalic dogs.



Example of CT transverse images in soft tissue algorithm, pre- (A) and post-contrast (B) of the cervical region of a brachycephalic dog. WL= 40; WW = 400. The slice location is at the middle aspect of the thyroid gland (black arrowheads), ventral to the third cervical vertebrae (C3). The thyroid gland in the pre-contrast series is isoattenuating to the *longus capitis muscle* (Lca) located dorsally to the gland. WW, window width; WL, window level.

407x174mm (72 x 72 DPI)