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Original Article

Age-dependent differences in hyoid bone position and shape in thyroglossal duct cyst: a three-dimensional computed tomography case–control study

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Abstract

Purpose The thyroglossal duct cyst (TGDC) is closely related to the hyoid bone, whose central segment is resected in the Sistrunk procedure, yet hyoid morphology in TGDC has only been examined two-dimensionally in pre-school children. This first age-stratified three-dimensional CT (3D-CT) study aimed to determine whether hyoid size, shape and position differ between TGDC patients and controls and whether this depends on age.

Methods Neck CT scans of 30 patients with TGDC and 30 controls frequency-matched by age stratum (0–18, 19–50 and ≥ 51 years) were reconstructed in 3D, and 11 size, shape and positional parameters were measured. Logistic regression and ROC analyses were performed in adults.

Results TGDC patients had a lower right greater cornu height ($p = 0.031$), a greater hyoid–vertebral distance ($p = 0.014$) and a wider inter-greater-cornu angle ($p = 0.048$) than controls. In children, no parameter differed between groups; differences were concentrated in the 19–50-year stratum (hyoid–vertebral distance 6.35 ± 1.41 vs 4.68 ± 0.75 mm, $p < 0.001$; angle $p = 0.008$; smaller greater cornu heights and body width). In adults, each 1-mm decrease in body width (OR 1.69, 95% CI 1.08–2.65) and each 1-mm increase in hyoid–vertebral distance (OR 1.74, 1.04–2.89) were independently associated with TGDC; AUCs were 0.80 (distance) and 0.77 (angle). Sexual dimorphism present in controls was absent in TGDC.

Conclusion Adult, but not paediatric, TGDC is associated with an anteriorly positioned, wider-angled hyoid with lower greater cornua and a narrower body, suggesting age-related perihyoid remodelling relevant to planning the Sistrunk procedure.

Keywords Hyoid bone · Thyroglossal cyst · Multidetector computed tomography · Three-dimensional imaging · Morphometry · Sistrunk procedure

Introduction

The thyroglossal duct cyst (TGDC) is the most common congenital anterior neck mass. It arises from persistence of epithelial remnants of the thyroglossal duct along the descent path of the thyroid primordium from the foramen caecum to the infrahyoid neck, and about half of the lesions lie at the level of the hyoid bone, to which the tract is closely applied and around which it typically loops [3, 25]. Although traditionally regarded as a paediatric condition, TGDC has a bimodal age distribution and a substantial proportion of patients present in adulthood, often with atypical complaints [19].

Since Sistrunk's description in 1920, en bloc excision of the cyst, the tract and the central segment of the hyoid body has been the standard of care [22]. Recurrence after a Sistrunk procedure is reported in approximately 5–6% of cases in large series and is largely attributed to incomplete removal of perihyoid and suprahyoid ductal tissue, whereas simple cystectomy carries a much higher risk [1, 9, 20, 24, 27]. The concept of a "posterior hyoid space", bounded by the posterior surface of the hyoid and the thyrohyoid membrane, has been proposed to explain part of this failure and to guide a more complete perihyoid dissection [15]. Hyoid anatomy is therefore of direct relevance to the surgical management of TGDC.

The hyoid is the only bone of the neck without a bony articulation; it is suspended by muscles and ligaments, and its morphology and position vary with sex, age, stature, craniofacial pattern and head posture [2, 4, 6, 11, 17, 21]. Three-dimensional computed tomography (3D-CT) has made reproducible, multi-parameter morphometry of the living hyoid possible and has documented marked sexual dimorphism, age-related fusion of the greater cornua with the body extending into adulthood, and considerable inter-individual variation in shape [5, 7, 8, 10, 12, 13, 14, 16, 23].

Whether TGDC is accompanied by, or predisposed by, an altered hyoid morphology has, to our knowledge, been examined in only one study, which was limited to pre-school

children: a midsagittal CT analysis that reported a wider and thicker hyoid body in TGDC [26]. No study has compared a comprehensive set of 3D hyoid parameters between patients with TGDC and controls, nor examined whether such differences depend on age. We hypothesised that a persistent thyroglossal tract and cyst, situated anterior to the hyoid body, may be associated with measurable differences in hyoid size, shape and position relative to the cervical spine, and that these differences may emerge with skeletal maturation. The aim of this study was to compare 11 3D-CT morphometric parameters of the hyoid bone between patients with TGDC and age-matched controls, overall and within paediatric, young-adult and older-adult strata, and to explore the discriminative value of the parameters that differed in adults.

Materials and methods

Study design and ethics

This retrospective case–control study was conducted in the Department of Otorhinolaryngology, Sakarya University Faculty of Medicine, at Sakarya University Training and Research Hospital, a tertiary referral centre. The protocol was approved by the Health Sciences Scientific Research Ethics Committee of Sakarya University Faculty of Medicine (17 June 2025; No. E-43012747-050.04-481652-367), and the study was performed in accordance with the Declaration of Helsinki. The study is reported in accordance with the STROBE statement for observational studies (checklist provided as Online Resource 1). Owing to the retrospective design and the use of anonymised imaging data, the requirement for individual informed consent was waived by the committee.

Participants

The hospital records of all patients diagnosed with TGDC in our department between 1 January 2009 and 1 May 2025 were screened. Patients whose diagnostic work-up included a neck CT examination were eligible; patients evaluated by ultrasonography and/or magnetic

resonance imaging only were not included. Of the 35 eligible patients, five were excluded because their CT data could no longer be retrieved from the picture archiving and communication system, leaving 30 patients in the TGDC group. In all patients, the diagnosis of TGDC was confirmed by histopathological examination of the surgical specimen.

The control group comprised 30 individuals who underwent neck CT in our institution between 1 January 2015 and 30 June 2025 for other head and neck indications, such as evaluation of cervical lymphadenopathy, lateral neck masses, salivary gland disease or vocal fold paralysis; none had a cystic lesion of the anterior neck. Controls were frequency-matched to the TGDC group by age stratum, so that both groups contained 12 participants aged 0–18 years, 12 aged 19–50 years and 6 aged ≥ 51 years.

For both groups, inclusion required an age of 0–90 years and a CT data set of adequate quality for 3D reconstruction of the hyoid bone. Exclusion criteria were a history of trauma or surgery involving the hyoid bone or cervical spine and a diagnosis of laryngeal carcinoma.

Imaging and morphometric measurements

All examinations had been acquired on the same 64-detector-row scanner (Aquilion 64; Toshiba Medical Systems, Otawara, Japan) in the Department of Radiology. DICOM data were transferred to a dedicated workstation (Advantage Workstation, AW; GE Healthcare, Chicago, IL, USA), on which volume-rendered 3D reconstructions of the hyoid bone and cervical spine were generated. All measurements were performed on these reconstructions by a single radiologist with 15 years of experience (L.T.A.), who was not informed of group allocation. To minimise measurement bias, all parameters were measured on bone-only volume-rendered reconstructions, in which soft tissues, including the cyst, were not displayed, using predefined bony landmarks. Linear measurements were recorded in millimetres and angles in degrees.

Eleven parameters were assessed, adapted from the protocol of Tarifi et al. [23] (Fig. 1): (1) anteroposterior (AP) length, the maximum distance between the anterior surface of the

body and the midpoint of a line tangent to the posterior tips of both greater cornua (Fig. 1a); (2, 3) right and left greater cornu length, from the junction with the body to the posterior tip (Fig. 1b, c); (4, 5) right and left greater cornu height, the vertical extent of each greater cornu in the coronal plane (Fig. 1d, e); (6) body width, the maximum transverse dimension of the body (Fig. 1f); (7) body height, the maximum vertical dimension of the body (Fig. 1g); (8) inter-cornual distance, between the inner aspects of the posterior tips of the greater cornua (Fig. 1h); (9) inter-greater-cornu angle, formed by lines drawn along each greater cornu from its posterior tip to its most anterior point and extended to their intersection anterior to the body (Fig. 1i); (10) hyoid–vertebral distance, the shortest distance between the posterior tip of the hyoid and the anterior surface of the cervical vertebral column (Fig. 1j); and (11) the cervical vertebral level at which the hyoid body was projected (Fig. 1k).

Statistical analysis

Analyses were performed with SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Data are presented as mean ± standard deviation or number (%). According to normality (Kolmogorov–Smirnov test), two groups were compared with the independent-samples t test or Mann–Whitney U test, and the three age strata with one-way analysis of variance (Tukey or Tamhane post hoc tests) or the Kruskal–Wallis test (Bonferroni-corrected post hoc comparisons); categorical variables were compared with the chi-square or Fisher's exact test. Effect sizes were expressed as Cohen's d.

Because no between-group difference was found in children, multivariable analyses were restricted to adults (≥ 19 years; n = 18 per group). Body width, hyoid–vertebral distance and inter-greater-cornu angle were entered into a binary logistic regression model with TGDC status as the dependent variable, and the two positional parameters were evaluated by receiver operating characteristic (ROC) analysis, with the area under the curve (AUC) and its Hanley–

McNeil 95% confidence interval (CI) and with sensitivity, specificity and predictive values at candidate cut-offs. Two-sided $p < 0.05$ was considered significant.

Results

Study population and overall comparison

Sixty participants were analysed. The TGDC and control groups were comparable in age (28.2 ± 20.7 vs 32.4 ± 21.5 years, $p = 0.407$), age-stratum distribution and sex (male 73.3% vs 63.3%, $p = 0.405$). The hyoid body was most often projected at the level of C3 in both groups (56.7% vs 76.7%), followed by C4 (40.0% vs 23.3%); one TGDC patient had a C2-level hyoid. The distribution of vertebral levels did not differ significantly between groups ($p = 0.165$) (Table 1).

Between-group comparisons of the ten metric parameters are shown in Table 2 and Fig. 2. Patients with TGDC had a significantly lower right greater cornu height (5.87 ± 1.38 vs 6.81 ± 1.89 mm, $p = 0.031$; $d = 0.57$), a greater hyoid–vertebral distance (6.74 ± 1.72 vs 5.78 ± 1.83 mm, $p = 0.014$; $d = 0.54$) and a wider inter-greater-cornu angle (45.9 ± 9.1° vs 42.3 ± 11.3°, $p = 0.048$; $d = 0.35$) than controls. Left greater cornu height was also lower in TGDC, without reaching significance (5.90 ± 1.07 vs 6.51 ± 1.52 mm, $p = 0.081$). AP length, greater cornu lengths, body width and height, and inter-cornual distance did not differ between groups.

Age- and sex-stratified comparisons

When the groups were compared within age strata (Table 3), none of the parameters differed between children with TGDC and paediatric controls (all $p > 0.05$). In contrast, in the 19–50-year stratum, patients with TGDC had lower right (6.66 ± 1.17 vs 7.98 ± 1.23 mm, $p = 0.014$) and left (6.30 ± 0.81 vs 7.44 ± 0.91 mm, $p = 0.004$) greater cornu heights, a narrower body (21.7 ± 3.4 vs 24.9 ± 2.6 mm, $p = 0.019$), a markedly greater hyoid–vertebral distance (6.35 ± 1.41 vs 4.68 ± 0.75 mm, $p < 0.001$) and a wider inter-greater-cornu angle (45.4 ± 10.8°

vs 35.7 ± 4.0°, p = 0.008). In participants aged ≥ 51 years, only the right greater cornu height remained significantly lower in TGDC (6.03 ± 1.34 vs 7.98 ± 1.13 mm, p = 0.022), with left greater cornu height, body width, hyoid–vertebral distance and inter-greater-cornu angle showing non-significant differences in the same direction as in younger adults.

Within-group comparisons across age strata (Online Resource 2) showed the expected growth-related increase of all linear dimensions from childhood to adulthood in both groups. Positional parameters, however, behaved differently. In controls, hyoid–vertebral distance and inter-greater-cornu angle varied significantly across age strata (p = 0.020 and p = 0.015), being largest in children (6.62 ± 1.74 mm and 48.4 ± 13.2°) and smallest in the 19–50-year stratum (4.68 ± 0.75 mm and 35.7 ± 4.0°). In patients with TGDC, neither hyoid–vertebral distance (6.75 ± 1.75, 6.35 ± 1.41 and 7.50 ± 2.23 mm; p = 0.670) nor inter-greater-cornu angle (44.3 ± 8.0°, 45.4 ± 10.8° and 50.1 ± 7.5°; p = 0.448) changed with age, so that adult TGDC hyoids retained the anterior position and wide angle observed in children.

In the control group, males had significantly larger values than females for AP length, both greater cornu lengths and heights, and body width and height, whereas the inter-greater-cornu angle was wider in females (48.5 ± 13.9° vs 38.8 ± 7.7°, p = 0.023); inter-cornual distance and hyoid–vertebral distance did not differ by sex (Table 4). In the TGDC group, none of the ten metric parameters differed between males (n = 22) and females (n = 8) (all p > 0.05).

Multivariable and ROC analyses in adults

In adults, body width, hyoid–vertebral distance and inter-greater-cornu angle were entered into a logistic regression model (Table 5). A narrower body and a greater hyoid–vertebral distance were independently associated with TGDC: the odds of TGDC increased 1.69-fold (95% CI 1.08–2.65; p = 0.023) for every 1-mm decrease in body width (equivalently, OR 0.59 per 1-mm increase) and 1.74-fold (95% CI 1.04–2.89; p = 0.034) for every 1-mm

increase in hyoid–vertebral distance. The inter-greater-cornu angle showed a borderline association (OR 1.11 per degree, 95% CI 1.00–1.24; p = 0.058).

In ROC analysis restricted to adults (Fig. 3), hyoid–vertebral distance discriminated TGDC from controls with an AUC of 0.80 (95% CI 0.65–0.95; p = 0.002) and the inter-greater-cornu angle with an AUC of 0.77 (95% CI 0.61–0.93; p = 0.004). A hyoid–vertebral distance of ≥ 5.60 mm yielded a sensitivity and specificity of 77.8% each, and an inter-greater-cornu angle of ≥ 40.6° yielded a sensitivity of 83.3% and a specificity of 77.8% (Table 5).

Discussion

In this 3D-CT study, patients with TGDC differed from age-matched controls in the position and shape, rather than the overall size, of the hyoid bone: the hyoid lay farther from the cervical spine, its greater cornua diverged at a wider angle and were vertically lower, and, in adults, the body was narrower. These differences were absent in children and were most pronounced between 19 and 50 years of age; in adults, hyoid–vertebral distance and inter-greater-cornu angle discriminated TGDC from controls with moderate accuracy. To our knowledge, this is the first multi-parameter, age-stratified comparison of hyoid morphology between TGDC patients and controls.

The only previous comparative study, in 29 children aged 3–4 years, reported a larger hyoid body “width” and thickness in TGDC on midsagittal CT images [26]. Because that study measured the sagittal dimensions of the body on a single two-dimensional slice, its parameters are not directly comparable with the transverse body width or the 3D positional measures used here, and its findings cannot be tested against our paediatric stratum, in which no parameter differed. In adults, we found the opposite tendency, a narrower body in TGDC, which was an independent predictor in the multivariable model. Taken together, the two studies at least agree that TGDC is not accompanied by a uniformly “normal” hyoid, and they underline that age and measurement plane must be specified when hyoid morphometry is reported.

The age dependence of our findings is, in our view, the most informative result. Cephalometric and CT studies show that the hyoid descends and moves in close conjunction with the mandible, pharynx and cervical spine during growth, and that its position stabilises in early adulthood [2, 4, 6, 11, 21]. Fusion of the greater cornua with the body, which is incomplete in childhood, progresses after the age of 20 and remains variable in adults [8, 12, 16, 18]. Consistently, our controls showed a clear maturational pattern: from childhood to young adulthood the hyoid approached the vertebral column and the greater cornua converged, the angle being narrowest at 19–50 years, in agreement with Dursun et al., who found the narrowest angle in the third and fourth decades [5]. Patients with TGDC did not display this pattern; their hyoid retained a childhood-like anterior position and wide angle into adulthood, while the greater cornua were vertically lower and the body narrower. Two, not mutually exclusive, explanations may be proposed. First, a persistent thyroglossal tract with its cyst, and the fibrosis or repeated inflammation that frequently accompany it, occupy the midline immediately anterior to and around the hyoid body and may alter the balance of suprahyoid and infrahyoid muscle tension vectors, thereby impeding the normal posterior approximation and remodelling of the bone during and after adolescence. Second, a pre-existing anteriorly positioned, wide-angled hyoid could itself modify midline soft-tissue dynamics and favour cystic dilatation of a ductal remnant, so that morphology would be a predisposing rather than a consequential feature. Our cross-sectional design cannot distinguish between these possibilities, but the absence of any difference in children argues against a purely congenital hyoid anomaly and favours an acquired, age-related process.

The sexual dimorphism observed in our controls agrees closely with the literature. Males had larger linear dimensions of the body and greater cornua, whereas the inter-greater-cornu angle was wider in females (48.5° vs 38.8°); Fakhry et al. reported the same pattern in adults, with a wider angle in females (44.1° vs 38.8°) [7], and greater male dimensions have

been documented in Japanese, Jordanian and Turkish populations [5, 10, 13, 14, 23]. Interestingly, this dimorphism was not detectable in the TGDC group. Although the small number of female patients (n = 8) limits the power of this comparison, the finding is compatible with the notion that the disease-related influence on hyoid shape overrides sex-specific growth patterns and should be revisited in larger series.

The hyoid was projected at the C3 level in most participants of both groups, in line with previous CT series reporting C3 as the predominant level in 37–69% of adults [5, 10], and the level distribution did not differ between groups. The positional difference we observed is therefore predominantly horizontal (anterior displacement away from the spine) rather than vertical, which is anatomically consistent with a midline lesion located anterior to the hyoid body.

These findings have practical implications. Recurrence after the Sistrunk procedure is most often attributed to residual perihyoid or suprahyoid ductal tissue, and systematic clearance of the posterior hyoid space and of the tissue between the hyoid and the thyrohyoid membrane has been associated with very low recurrence rates [9, 15, 20, 24, 27]. An anteriorly displaced hyoid with widely divergent greater cornua may be accompanied by a larger perihyoid compartment, including the posterior hyoid space between the bone and the thyrohyoid membrane, in which residual tract is thought to persist [15]. Awareness of this configuration on preoperative CT may encourage the surgeon to secure an adequate central hyoid resection and a deliberate posterior dissection, particularly in adult patients, who more often present with atypical symptoms and after episodes of infection [19]. We emphasise that the ROC-derived cut-off values (hyoid–vertebral distance ≥ 5.6 mm, inter-greater-cornu angle ≥ 40.6°) are exploratory descriptors of an anatomical association with moderate discriminative ability (AUC 0.77–0.80); TGDC remains a clinical and imaging diagnosis, and these values are not

proposed as diagnostic tests, nor should they be applied to children, in whom no difference was found.

The strengths of this study are the use of standardised 3D reconstructions rather than two-dimensional slices, the assessment of a comprehensive set of size, shape and positional parameters, measurements by an experienced radiologist on bone-only reconstructions using predefined landmarks, an age-frequency-matched control group and stratified analyses that revealed the age dependence of the association. Several limitations must be acknowledged. The study was retrospective and single-centre, and the sample was small, particularly in the ≥ 51-year stratum (n = 6 per group) and among female patients, so that non-significant results may reflect a lack of power and significant results with modest effect sizes (for example the inter-greater-cornu angle, $p = 0.048$, $d = 0.35$) should be interpreted with caution. Multiple comparisons across eleven parameters and several strata were performed without formal correction, and the logistic regression model was fitted with 18 events for three covariates, below the commonly recommended ten events per variable; these analyses should therefore be regarded as exploratory. Although the observer was not informed of group allocation, complete blinding could not be guaranteed, because the cyst may have been visible on the source axial images used to generate the reconstructions. All measurements were obtained by a single observer; intra- and inter-observer reliability were not assessed. Head and neck position, the phase of swallowing and the indications for CT in the control group were not standardised, and hyoid position is known to be sensitive to head posture [2, 21]. Cyst size, location and infection history were not analysed in relation to hyoid parameters, and the cross-sectional design precludes causal inference. Finally, our control group consisted of patients imaged for other clinical reasons rather than healthy volunteers, which is unavoidable for CT-based studies but may introduce selection bias.

Conclusion

Three-dimensional CT morphometry shows that adult patients with TGDC have an anteriorly positioned, wider-angled hyoid bone with lower greater cornua and a narrower body, whereas children with TGDC do not differ from controls. These age-dependent differences suggest an acquired remodelling of the perihyoid region in TGDC and draw attention to the perihyoid and posterior hyoid space in the planning of the Sistrunk procedure in adults. Larger, prospective studies with reliability testing and correlation with cyst characteristics and surgical outcome are needed to clarify whether hyoid morphology is a consequence of, or a predisposing factor for, thyroglossal duct cyst.

Declarations

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Competing interests The authors have no relevant financial or non-financial interests to disclose.

Ethics approval This retrospective study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Health Sciences Scientific Research Ethics Committee of Sakarya University Faculty of Medicine (17 June 2025; No. E-43012747-050.04-481652-367).

Consent to participate The requirement for informed consent was waived by the ethics committee because of the retrospective design and the use of anonymised imaging data.

Consent to publish Not applicable; the manuscript contains no identifiable patient information or images.

Author contributions İ.H.İ. and M.G. conceived and designed the study. İ.H.İ. and H.E. collected the clinical data. L.T.A. performed the three-dimensional CT reconstructions and all morphometric measurements and provided the images for Figure 1. E.M.G. contributed to the anatomical methodology and the interpretation of the morphometric findings. İ.H.İ. and A.F.E. performed the statistical analysis. İ.H.İ. and A.F.E. wrote the main manuscript text and prepared Figures 2 and 3 and the tables. M.G. supervised the study. M.G., L.T.A., E.M.G. and H.E. critically revised the manuscript. All authors read and approved the final manuscript.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Table 1 Demographic characteristics and vertebral level of the hyoid body in the thyroglossal duct cyst (TGDC) and control groups

	TGDC (n = 30)	Control (n = 30)	p
Age (years), mean ± SD	28.2 ± 20.7	32.4 ± 21.5	0.407
Age stratum, n (%)			0.999
0–18 years	12 (40.0)	12 (40.0)	
19–50 years	12 (40.0)	12 (40.0)	
≥ 51 years	6 (20.0)	6 (20.0)	
Sex, n (%)			0.405
Male	22 (73.3)	19 (63.3)	
Female	8 (26.7)	11 (36.7)	
Vertebral level of hyoid body, n (%)			0.165
C2	1 (3.3)	0 (0)	
C3	17 (56.7)	23 (76.7)	
C4	12 (40.0)	7 (23.3)	

Data are mean ± standard deviation or n (%). p values from the independent-samples t test (age) and chi-square or Fisher's exact test (categorical variables)

Table 2 Comparison of three-dimensional CT morphometric parameters of the hyoid bone between the TGDC and control groups

Parameter	TGDC (n = 30)	Control (n = 30)	p	Cohen's d
AP length (mm)	35.55 ± 5.99	33.85 ± 7.08	0.321	0.26
Right greater cornu length (mm)	25.11 ± 5.74	25.38 ± 5.44	0.982	0.05
Left greater cornu length (mm)	24.78 ± 5.41	24.75 ± 6.02	0.984	0.01
Right greater cornu height (mm)	5.87 ± 1.38	6.81 ± 1.89	0.031*	0.57
Left greater cornu height (mm)	5.90 ± 1.07	6.51 ± 1.52	0.081	0.46
Body width (mm)	20.34 ± 4.43	21.37 ± 5.59	0.434	0.20
Body height (mm)	10.80 ± 2.06	11.35 ± 2.27	0.331	0.25
Inter-cornual distance (mm)	33.36 ± 6.62	35.85 ± 6.62	0.150	0.38
Hyoid–vertebral distance (mm)	6.74 ± 1.72	5.78 ± 1.83	0.014*	0.54
Inter-greater-cornu angle (°)	45.92 ± 9.10	42.34 ± 11.25	0.048*	0.35

Data are mean ± standard deviation. p values from the independent-samples t test or Mann–Whitney U test according to distribution. Cohen's d calculated from group means and standard deviations. *p < 0.05. AP anteroposterior

414 **Table 3** Age-stratified comparison of hyoid bone parameters between the TGDC and control groups

Parameter	TGDC	Control	p
0–18 years (n = 12 per group)			
AP length (mm)	30.29 ± 4.87	26.99 ± 5.71	0.143
Right greater cornu length (mm)	19.50 ± 4.65	20.42 ± 4.57	0.621
Left greater cornu length (mm)	19.87 ± 4.48	18.99 ± 4.54	0.637
Right greater cornu height (mm)	4.99 ± 1.15	5.06 ± 1.32	0.884
Left greater cornu height (mm)	5.09 ± 0.89	5.15 ± 1.21	0.843
Body width (mm)	16.88 ± 3.41	15.63 ± 3.57	0.391
Body height (mm)	9.81 ± 2.10	9.67 ± 2.16	0.873
Inter-cornual distance (mm)	28.20 ± 4.90	31.81 ± 7.46	0.101
Hyoid–vertebral distance (mm)	6.75 ± 1.75	6.62 ± 1.74	0.999
Inter-greater-cornu angle (°)	44.33 ± 7.96	48.43 ± 13.17	0.368
19–50 years (n = 12 per group)			
AP length (mm)	38.17 ± 3.53	38.54 ± 3.41	0.799
Right greater cornu length (mm)	28.49 ± 2.35	29.35 ± 3.20	0.459
Left greater cornu length (mm)	27.87 ± 3.00	28.57 ± 3.37	0.597
Right greater cornu height (mm)	6.66 ± 1.17	7.98 ± 1.23	0.014*
Left greater cornu height (mm)	6.30 ± 0.81	7.44 ± 0.91	0.004*
Body width (mm)	21.73 ± 3.39	24.87 ± 2.61	0.019*
Body height (mm)	11.23 ± 1.86	12.10 ± 1.45	0.215
Inter-cornual distance (mm)	35.65 ± 4.97	38.05 ± 4.15	0.378
Hyoid–vertebral distance (mm)	6.35 ± 1.41	4.68 ± 0.75	< 0.001*
Inter-greater-cornu angle (°)	45.41 ± 10.79	35.72 ± 3.95	0.008*
≥ 51 years (n = 6 per group)			
AP length (mm)	40.81 ± 3.49	38.20 ± 2.32	0.162
Right greater cornu length (mm)	29.58 ± 2.92	27.35 ± 1.35	0.133
Left greater cornu length (mm)	28.41 ± 3.02	28.63 ± 2.71	0.899
Right greater cornu height (mm)	6.03 ± 1.34	7.98 ± 1.13	0.022*
Left greater cornu height (mm)	6.75 ± 0.78	7.38 ± 1.03	0.260
Body width (mm)	24.48 ± 3.05	25.83 ± 2.44	0.419
Body height (mm)	11.93 ± 1.69	13.21 ± 1.68	0.218
Inter-cornual distance (mm)	39.08 ± 5.63	39.55 ± 5.18	0.589
Hyoid–vertebral distance (mm)	7.50 ± 2.23	6.30 ± 2.57	0.409
Inter-greater-cornu angle (°)	50.11 ± 7.51	43.40 ± 11.11	0.252

415 Data are mean ± standard deviation. p values from the independent-samples t test or Mann–Whitney U test. *p <
416 0.05. AP anteroposterior
417

Table 4 Hyoid bone parameters according to sex within the TGDC and control groups

Parameter	TGDC (n = 30)			Control (n = 30)		
	Male (n = 22)	Female (n = 8)	p	Male (n = 19)	Female (n = 11)	p
AP length (mm)	35.80 ± 6.38	34.83 ± 5.06	0.672	36.27 ± 6.55	29.67 ± 6.15	0.004*
Right greater cornu length (mm)	25.03 ± 6.40	25.33 ± 3.68	0.558	26.89 ± 5.15	22.77 ± 5.13	0.033*
Left greater cornu length (mm)	24.85 ± 5.95	24.57 ± 3.87	0.707	26.73 ± 5.78	21.33 ± 4.97	0.011*
Right greater cornu height (mm)	5.93 ± 1.47	5.68 ± 1.18	0.642	7.59 ± 1.58	5.47 ± 1.64	0.002*
Left greater cornu height (mm)	5.90 ± 1.09	5.90 ± 1.06	0.984	7.10 ± 1.34	5.50 ± 1.31	0.004*
Body width (mm)	20.80 ± 4.72	19.08 ± 3.49	0.298	23.53 ± 5.04	17.62 ± 4.54	0.002*
Body height (mm)	11.09 ± 2.08	10.02 ± 1.89	0.207	12.16 ± 2.01	9.96 ± 2.10	0.011*
Inter-cornual distance (mm)	33.67 ± 6.96	32.48 ± 5.94	0.651	36.85 ± 6.80	34.12 ± 6.21	0.275
Hyoid–vertebral distance (mm)	6.95 ± 1.93	6.15 ± 0.70	0.541	5.76 ± 2.01	5.80 ± 1.57	0.703
Inter-greater-cornu angle (°)	45.71 ± 8.04	46.50 ± 12.18	0.869	38.76 ± 7.73	48.51 ± 13.91	0.023*

Data are mean ± standard deviation. p values from the independent-samples t test or Mann–Whitney U test. *p < 0.05. AP anteroposterior

Table 5 Multivariable logistic regression model for TGDC and diagnostic performance of hyoid–vertebral distance and inter-greater-cornu angle in adults (≥ 19 years; TGDC n = 18, controls n = 18)

A. Logistic regression

Covariate	β	SE	OR (95% CI) per unit increase	OR (95% CI) per unit decrease	p
Body width (per 1 mm)	−0.524	0.230	0.59 (0.38–0.93)	1.69 (1.08–2.65)	0.023*
Hyoid–vertebral distance (per 1 mm)	0.552	0.260	1.74 (1.04–2.89)	0.58 (0.35–0.96)	0.034*
Inter-greater-cornu angle (per 1°)	0.106	0.056	1.11 (1.00–1.24)	0.90 (0.80–1.00)	0.058
Constant	4.756	4.759	—	—	0.318

β regression coefficient, SE standard error, OR odds ratio, CI confidence interval. *p < 0.05

B. ROC analysis and candidate cut-off values

Parameter / cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
Hyoid–vertebral distance, AUC 0.80 (p = 0.002)				
≥ 5.40 mm	83.3	72.2	75.0	81.3
≥ 5.60 mm	77.8	77.8	77.8	77.8
≥ 5.85 mm	72.2	83.3	81.3	75.0
Inter-greater-cornu angle, AUC 0.77 (p = 0.004)				
≥ 38.80°	83.3	72.2	75.0	81.3
≥ 40.60°	83.3	77.8	78.9	82.4
≥ 42.35°	77.8	77.8	77.8	77.8

AUC area under the ROC curve (95% CI 0.65–0.95 and 0.61–0.93, Hanley–McNeil method), PPV positive predictive value, NPV negative predictive value

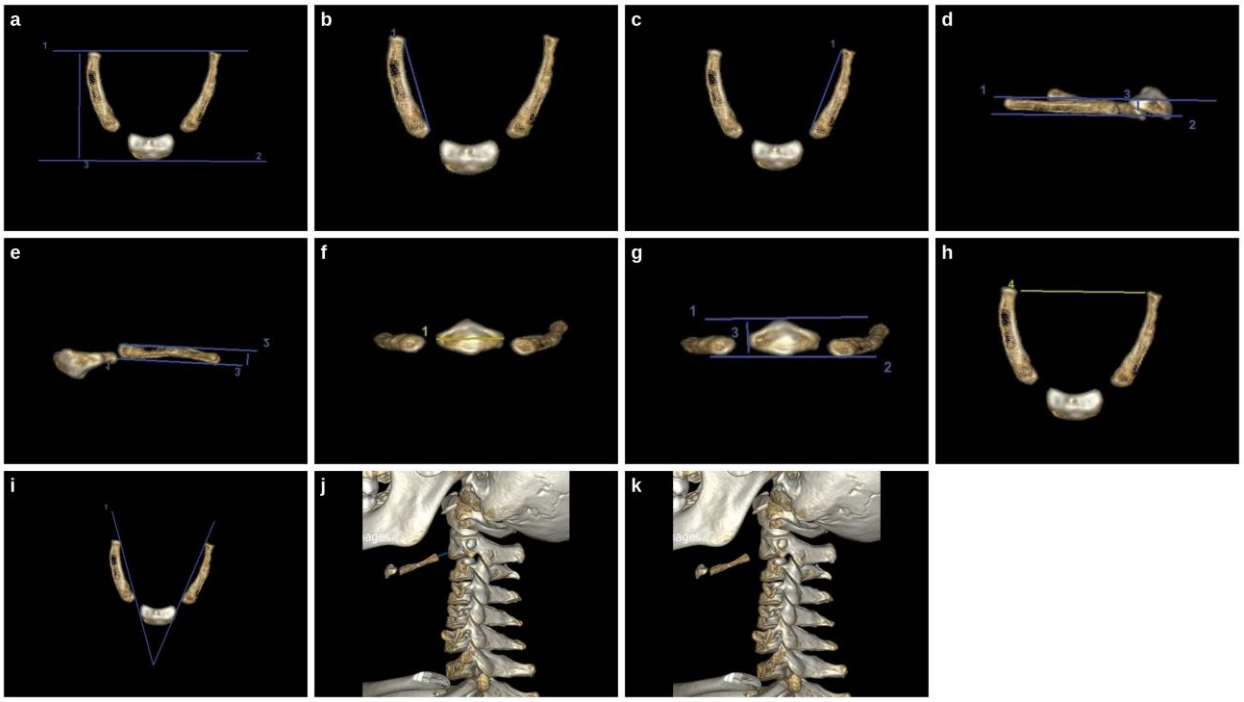
Figure legends

Fig. 1 Measurement technique on volume-rendered three-dimensional CT reconstructions of the hyoid bone. **a** Anteroposterior length: distance between the midpoint of a line tangent to the posterior tips of the greater cornua (1) and a parallel line tangent to the anterior surface of the body (2), measured along line 3. **b, c** Right and left greater cornu length (1). **d, e** Right and left greater cornu height in the coronal plane, i.e. the vertical distance (3) between lines tangent to the upper (1) and lower (2) margins. **f** Body width (1). **g** Body height (3) between tangents to the superior (1) and inferior (2) borders. **h** Inter-cornual distance between the inner aspects of the posterior tips of the greater cornua (4). **i** Inter-greater-cornu angle formed by lines drawn along the long axis of each greater cornu and extended to their anterior intersection (1). **j** Hyoid–vertebral distance between the posterior tip of the hyoid and the anterior surface of the cervical vertebral column (blue line). **k** Determination of the vertebral level of the hyoid body (here C3)

Fig. 2 Box plots of the three parameters that differed significantly between the thyroglossal duct cyst (TGDC) and control groups (n = 30 each). **a** Right greater cornu height ($p = 0.031$). **b** Hyoid–vertebral distance ($p = 0.014$). **c** Inter-greater-cornu angle ($p = 0.048$). Boxes indicate the interquartile range, horizontal lines the median, whiskers the range excluding outliers (circles)

Fig. 3 Receiver operating characteristic curves for the discrimination of TGDC from controls in adults (≥ 19 years; n = 18 per group). **a** Hyoid–vertebral distance, AUC 0.80 ($p = 0.002$). **b** Inter-greater-cornu angle, AUC 0.77 ($p = 0.004$). The diagonal line represents the reference (AUC 0.50)

453 **Fig. 1**



454

455

Fig. 2

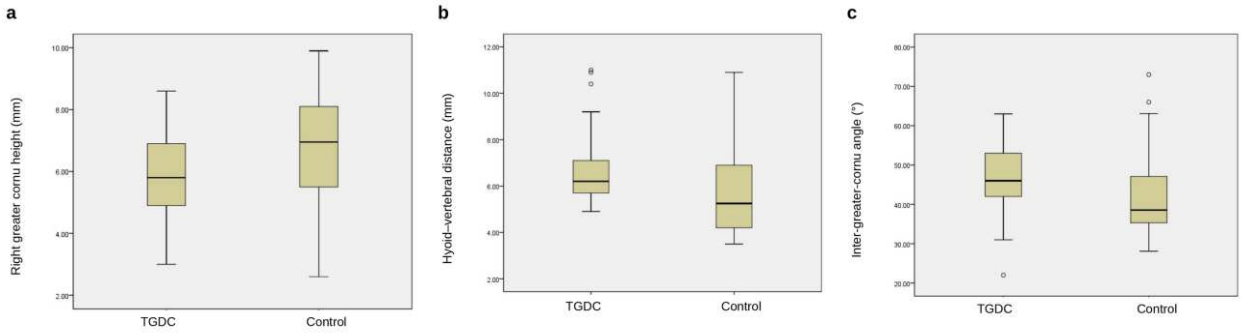
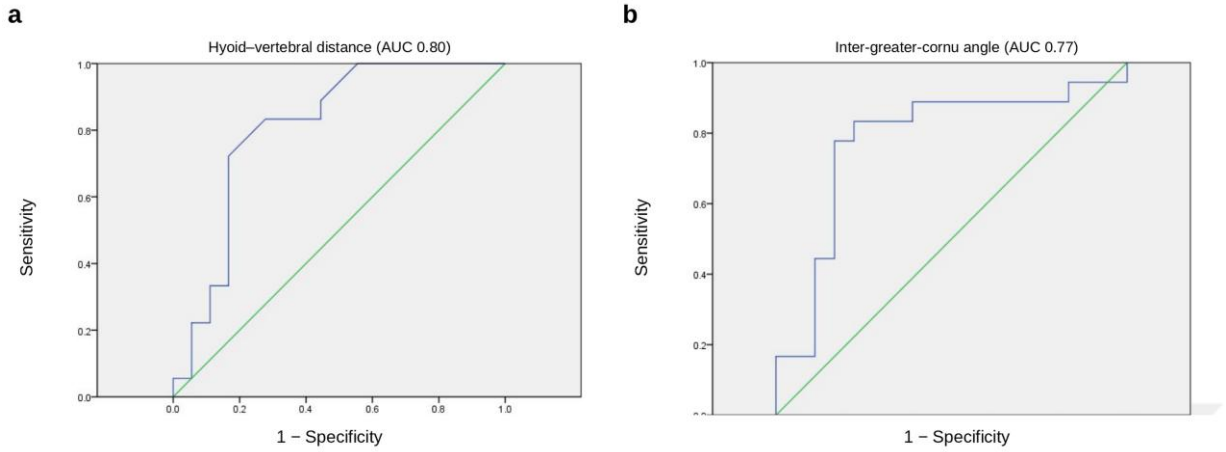

a
Right greater cornu height (mm)
TGDC
Control
b
Hyoid–vertebral distance (mm)
TGDC
Control
c
Inter-greater-cornu angle (°)
TGDC
Control

Fig. 3


a
Hyoid–vertebral distance (AUC 0.80)
Sensitivity
1 − Specificity
b
Inter-greater-cornu angle (AUC 0.77)
Sensitivity
1 − Specificity

Supplementary Files

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