



## Body Imaging

## Normal ultrasound anatomy and common anatomical variants of the thyroid gland plus adjacent structures — A pictorial review

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## ABSTRACT

**Background:** High-resolution ultrasound is considered the best imaging technique for evaluating the thyroid gland, as it is accessible, non-invasive, and highly sensitive concerning the detection and characterization of thyroid nodules.

However, a background knowledge of the normal ultrasound anatomy of the thyroid gland, adjacent structures, and its anatomical variants is crucial to avoid misdiagnosis in daily practice. Through this pictorial review, we intend to:

- 1- Briefly review the normal ultrasound anatomy of the thyroid gland and adjacent structures.
- 2- Identify and recognize the clinical relevance of common anatomical variants of thyroid gland and adjacent structures. Ultrasound images of anatomical variants of shape and size are displayed, including agenesis, hemi-agenesis, and all variations of accessory thyroid gland parenchyma: external, superior (pyramidal lobe or Lalouette's pyramid, thyroglossal duct cyst, lingual thyroid), posterior (Zuckerandl's tubercle or lobe), and inferior (mediastinal). Ectopic thyroid tissue and non-recurrent laryngeal nerve are represented. Some common artifacts are shown (muscle aponeurosis, septum, osteophytes, and oesophagus movement with neck rotation).

## 1. Introduction

## 1.1. Background

The evaluation of a patient with a possible thyroid disease should start with the anamnesis and family history registration, followed by the physical examination, and, if necessary, a TSH dosage should be requested.

A functional assessment of the thyroid gland or of a thyroid nodule can only be accomplished by Scintigraphy with either <sup>99m</sup>Tc pertechnetate or <sup>123</sup>I: planar images and/or Single Photon Emission Computed Tomography — CT (SPECT-CT). Scintigraphy with these two radiopharmaceuticals is indicated for the functional evaluation of thyroid nodules, ectopic thyroid tissue detection, and differential diagnosis of mediastinal masses [1,2]. Thyroid scintigraphy is indicated in the evaluation of thyroid nodules with TSH below normal values, [3]. The use of thyroid scintigraphy in the evaluation of thyroid nodules with normal TSH values is also useful, due to the high prevalence of hyperfunctioning nodules with normal TSH values, especially in iodine

deficiency countries [4].

High-resolution ultrasound is considered the best imaging technique for evaluating the thyroid gland, as it is accessible, non-invasive, and highly sensitive concerning the detection and characterization of thyroid nodules.

Ultrasound is limited by observer reproducibility. As such, background knowledge of the normal ultrasound anatomy of the thyroid gland, adjacent structures, and its anatomical variants is crucial to avoid misdiagnosis in daily practice.

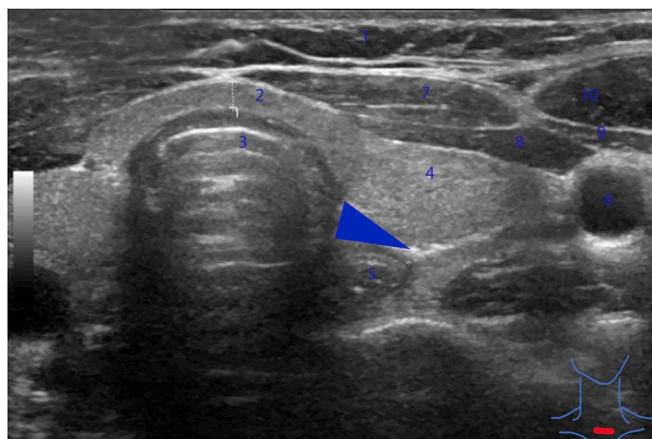
## 1.2. Objectives

Through this pictorial review we intend to:

- 1- Briefly review the normal ultrasound anatomy of the thyroid gland and adjacent structures.
- 2- Identify and recognize the clinical relevance of common anatomical variants of thyroid gland and adjacent structures. Ultrasound images of anatomical variants of shape and size are displayed, including

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**Fig. 1.** Normal thyroid transverse plane: 1—subcutaneous fat; 2—thyroid isthmus; 3—trachea; 4—left lobe; 5—oesophagus; 6—carotid artery; 7—sternohyoid; 8—sternothyroid; 9—omohyoid; 10—sternocleidomastoid; triangle—left tracheoesophageal groove.

agenesis, hemi-agenesis, and all variations of accessory thyroid gland parenchyma: external, superior (pyramidal lobe or Lalouette's pyramid, thyroglossal duct cyst, lingual thyroid), posterior (Zuckermandl's tubercle or lobe), and inferior (mediastinal). Ectopic thyroid tissue and non-recurrent laryngeal nerve are represented. Some common artifacts are shown (muscle aponeurosis, septum, osteophytes, and oesophagus movement with neck rotation).

**2. Overview of normal thyroid ultrasound/Doppler-ultrasound**

The normal thyroid gland is in the neck's infra-hyoid visceral space [5]. It produces the hormones T3 and T4, which have well-known important roles in growth and metabolism regulation.

The normal thyroid parenchyma is divided in multiple lobules, each one composed of 20 to 40 follicles with variable diameters. Follicles are spherical shaped cavities, filled with colloid and lined by a simple epithelium. Between the follicles, we can also find clusters of C-cells, or para-follicular cells, which produce calcitonin [6,7].

A connective tissue capsule covers the gland and sends septa into the parenchyma [6].

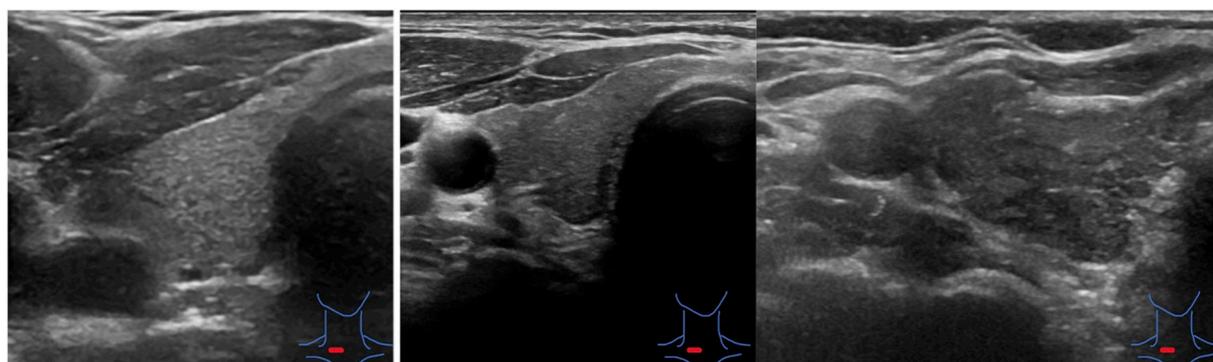
The ultrasound screening field must include the entire gland, both in the transversal and longitudinal planes, plus the neck lymph node chains, from submandibular to suprasternal. Doppler ultrasound can be used to characterize normal thyroid vascularization and to identify thyroid arteries and veins. Below we will describe in detail the images acquired in routine thyroid gland ultrasound examinations.

**2.1. Transverse plane**

Placing the transducer in a transversal plane (Fig. 1), over the midline anterior neck, from anterior to posterior, the following structures should be identified: skin; subcutaneous fat (with variable thickness), the strap muscles: superficial and medially located sternohyoid; deeper than the sternohyoid is the sternothyroid; the omohyoid is superficial and laterally located, under the sternocleidomastoid (ECM) and above the internal jugular vein (IJV) and carotid artery. In the midline, below the muscle layer, the thin isthmus of the thyroid gland can be observed, laterally connecting to the pyramid-shaped right and left lobes. Below the lateral lobes are the longus colli muscles [8,9]. The recurrent laryngeal nerve lies on the tracheoesophageal groove, on the left side, and between the trachea and the right lobe, on the right side.

Thyroid parenchyma should be homogeneous and more hyperechoic than the surrounding muscles. However, we routinely observe a gradient of gray shades ranging between the normal gland and the very hypoechoic thyroid of Hashimoto's disease [10] (Fig. 2).

The gland size varies with age, with gender, and among different geographic regions [11–13]. Normal ultrasonographic dimensions differ between children and adolescents/adults. The gland volume increases as infants and young children grow. There is no consensus about normal values for size variation with age. Rumack et al. [11] consider that the normal thyroid volume of a neonate ranges between 0.4 and 1.40 ml. Further, the author states that thyroid volume increases 1.0 to 1.3 ml per 10 kg of weight increase, until it reaches an adult normal value of 10–11 ± 3 ml. For Nataf et al. [12], the normal thyroid volume for a child < 99 cm height should range between 2.3 ± 0.7 ml, the normal volume for an adolescent should be > 16 ml; and the normal values for adult females and males should be > 18 ml and >



**Fig. 2.** Thyroid parenchyma heterogeneity — from hypoechoic thyroiditis (left) to normal (right).

**Table 1**  
Thyroid weight and size range based on age or height.

Age or height/authors	Rumack 2018 [7]	Nataf 2014 [8]	Riccabona 2014 (Austrian values) [9]	WHO 1997 [10]
Newborn	L-18–20 mm AP-8–9 mm Volume 0.4–1.4 ml			
1 year	L-25 mm AP-12–15 mm Volume 1.0 ± 1.3 ml			
≤ 6 years	Volume increases 1.0–1.3 ml per each 10 kg rise in body weight		> 4 ml	
6 years				Boys: 5.4 ml Girls: 5.0 ml
7 years				Boys: 5.7 ml Girls: 5.9 ml
8 years				Boys: 6.1 ml Girls: 6.9 ml
9 years				Boys: 6.8 ml Girls: 8.0 ml
10 years				Boys: 7.8 ml Girls: 9.2 ml
6–10 years			7.1 ± 3.5 ml	
11 years				Boys: 9.0 ml Girls: 10.4 ml
12 years				Boys: 10.4 ml Girls: 11.7 ml
13 years				Boys: 12.0 ml Girls: 13.1 ml
10–13 years			9.7 ± 6.6 ml	
14 years				Boys: 13.9 ml Girls: 14.6 ml
15 years				Boys: 16 ml Girls: 16.1 ml
13–15 years (teenagers)		> 16 ml	13.0 ± 8.9 ml	
15–17 years (teenagers)			14.1 ± 10.2 ml	
Adult male	L-40–60 mm	> 20 ml	< 18 ml	
Adult female	AP-13–18 mm Volume 10–11 ± 3 ml	> 18 ml	< 25 ml	
≤ 99 cm		2.3 ± 0.7 ml		
100–109 cm		3.3 ± 1.0 ml		
110–119 cm		4.1 ± 1.1 ml		
120–129 cm		4.9 ± 1.1 ml		
130–139 cm		6.3 ± 2.0 ml		
140–149 cm		7.4 ± 2.2 ml		
150–159 cm		8.5 ± 2.3 ml		
≥ 160 cm		10.9 ± 2.5 ml		



**Fig. 3.** In axial section, cervical oesophagus is normally on the left side of the trachea (arrow).



Fig. 4. In axial section, with left side neck rotation, cervical oesophagus can be perceived on the right side of the trachea (arrow).

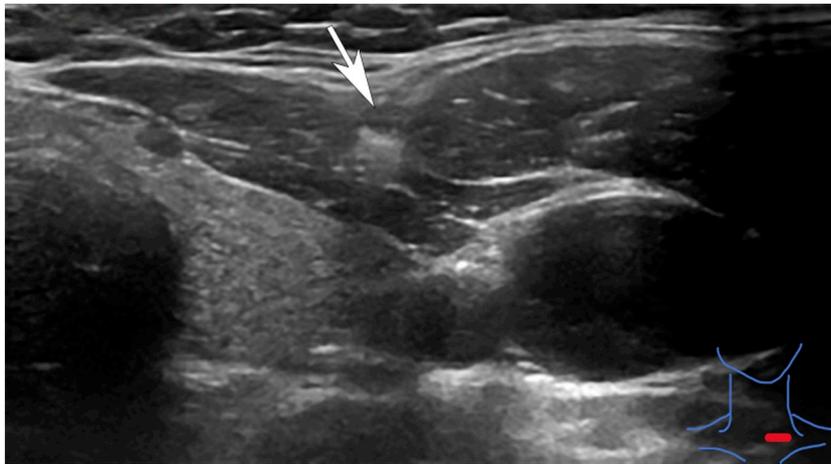


Fig. 5. In axial section, muscle aponeurosis can originate an acoustic shadow (arrow).

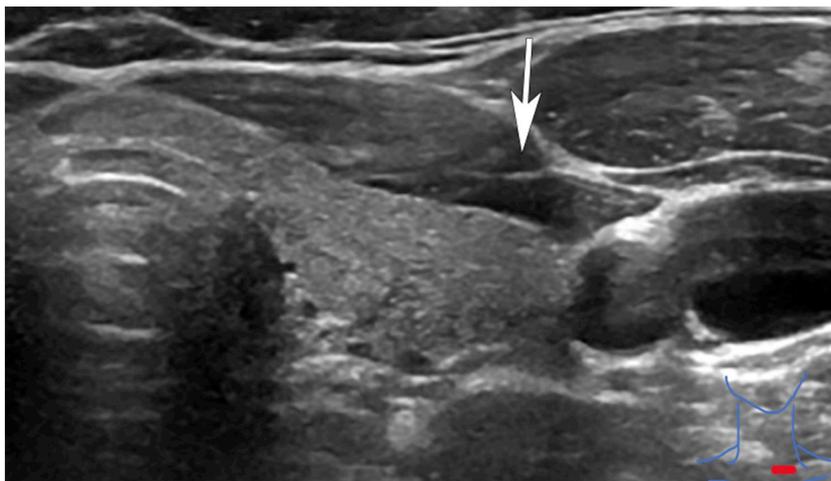


Fig. 6. Muscle aponeurosis acoustic shadow disappearance after moving the probe (arrow).

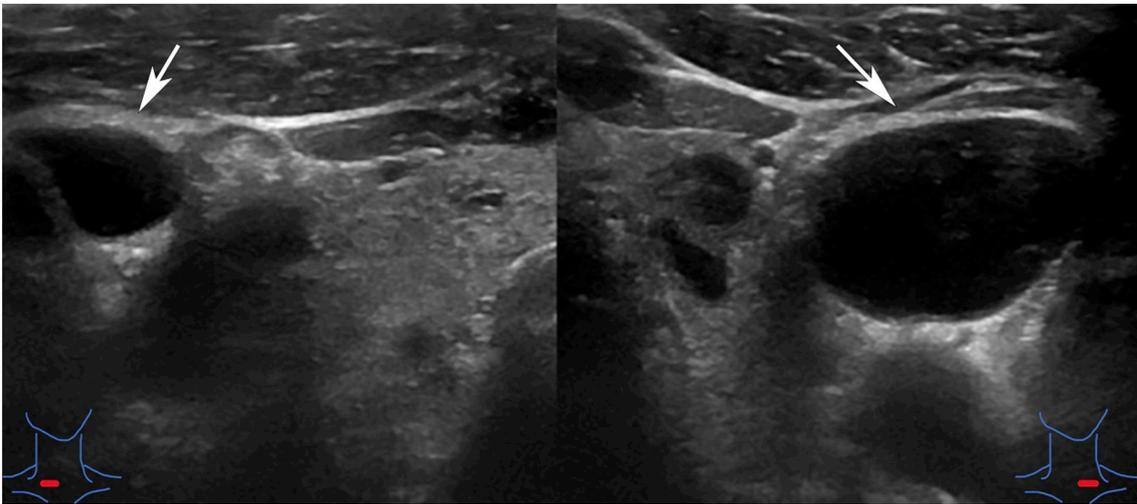


Fig. 7. Axial section: arrows point asymmetric internal jugular veins.

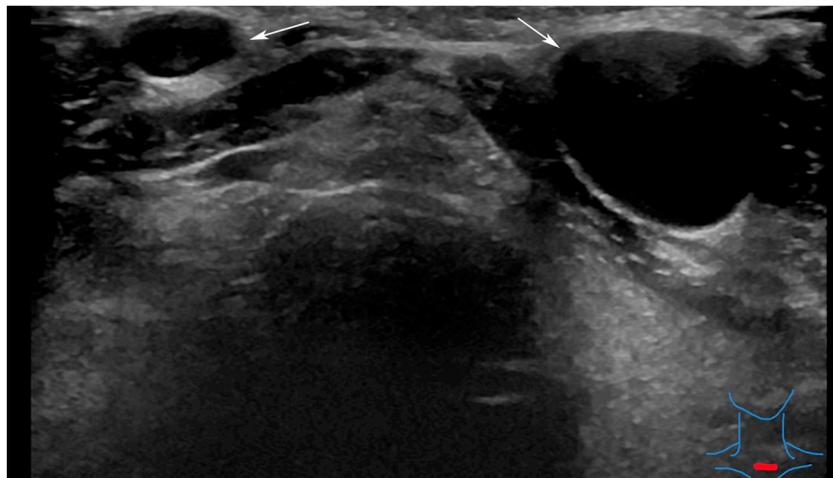


Fig. 8. Axial section: arrows point asymmetric anterior jugular veins.

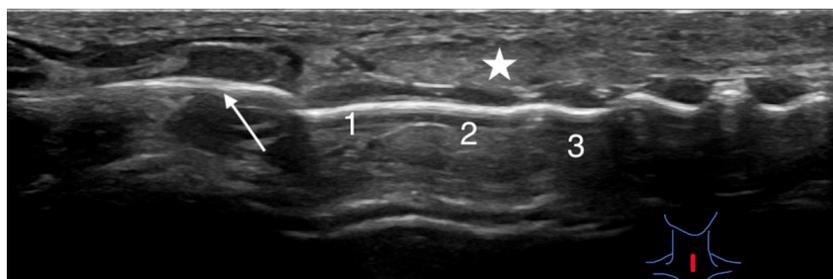


Fig. 9. Longitudinal plane, midline; arrow points to cricoid cartilage; star marks the thyroid isthmus, and the first tracheal rings are numbered.

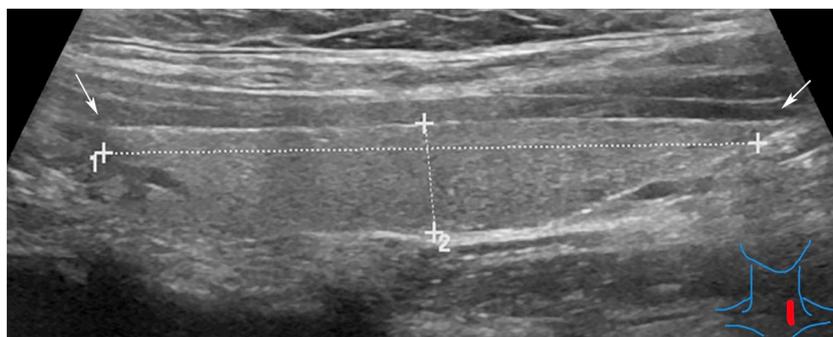


Fig. 10. Longitudinal plane, lateral lobe, arrows indicate angular shape outline of upper and inferior poles.

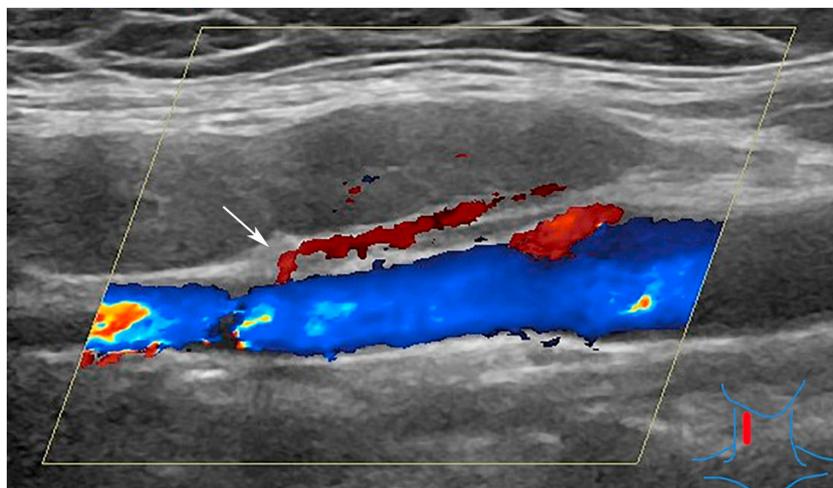


Fig. 11. Superior thyroid artery, running inferiorly from the external carotid artery — arrow in colour Doppler imaging.

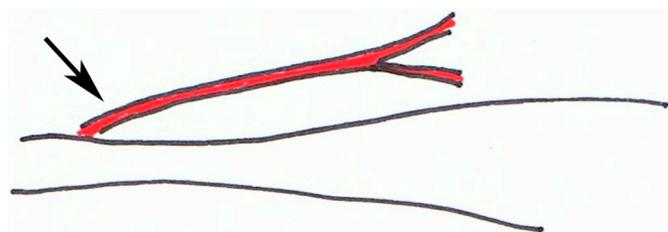


Fig. 12. Drawing matching Fig. 11 — superior thyroid artery, running inferiorly from the external carotid artery (arrow).

20 ml, respectively. This author also offers a table displaying thyroid volume increase in childhood and adolescence, based on height increase. Riccabona published normal thyroid volume and size range values based on age, for the Austrian population [13]. The WHO, in 1997, published a bulletin with ultrasonography determined values for thyroid volume in children aged 6–15 years [14] (Table 1).

The isthmus lies directly over the trachea, a convex, arciform structure which, due to the presence of luminal air, casts a posterior acoustic shadow and reverberation artifacts. Still in the midline, but above the trachea, we can perceive the thyroid cartilage and attached muscles [8]. Lateral to the thyroid lobes, on each side, stand the common carotid artery and the internal jugular vein.

Posterior to the left lobe and adjacent to the trachea, we can also see the oesophagus cut in the transversal plane (Fig. 1), identifiable by the layered wall “gut signature”. Eventually, the oesophagus might be mistaken for a nodule; to clear any doubts, one can simply ask the patient to swallow and view the air and saliva passing through. In alternative, we can rotate the transducer toward the longitudinal plane and verify that it is a tubular structure and, thus, not a nodule. Consider that the position of the oesophagus can vary with neck rotation. With left side rotation, the oesophagus can be perceived on the right side of the trachea (Figs. 3 and 4).

Note that the aponeurosis between the ECM and the sternohyoid and sternothyroid muscles frequently results in an acoustic shadow,

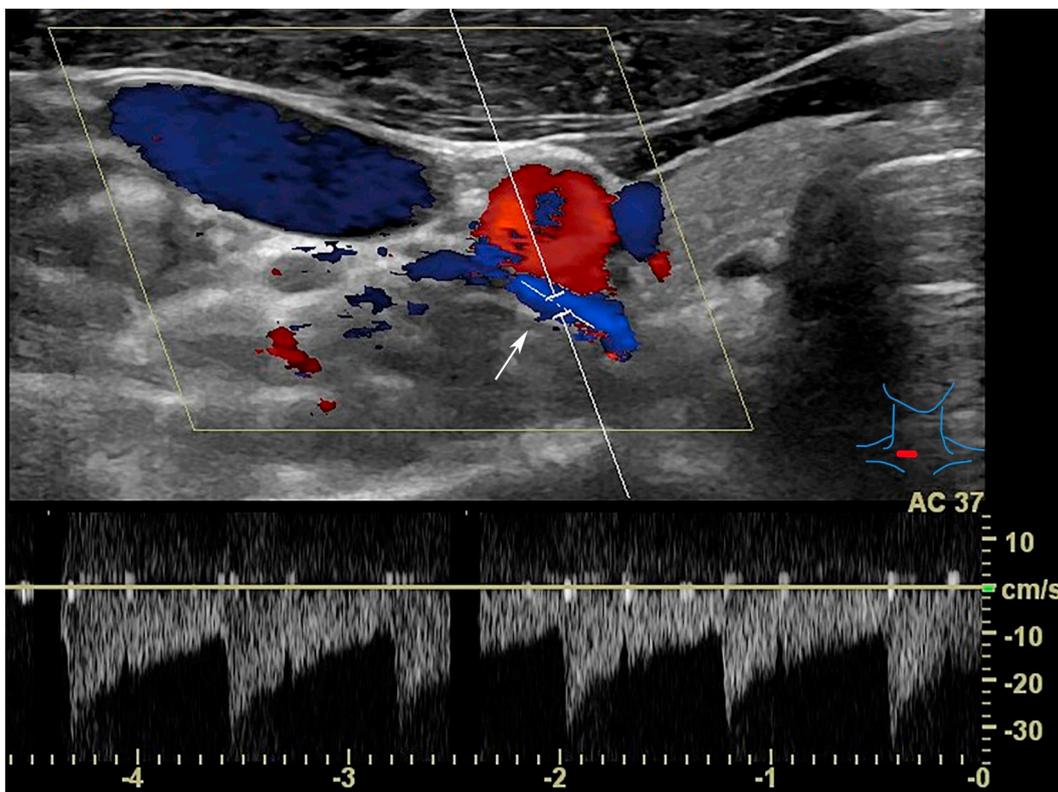


Fig. 13. Transversal plane Doppler image: the inferior thyroid artery (arrow) is seen posteriorly to the common carotid artery.

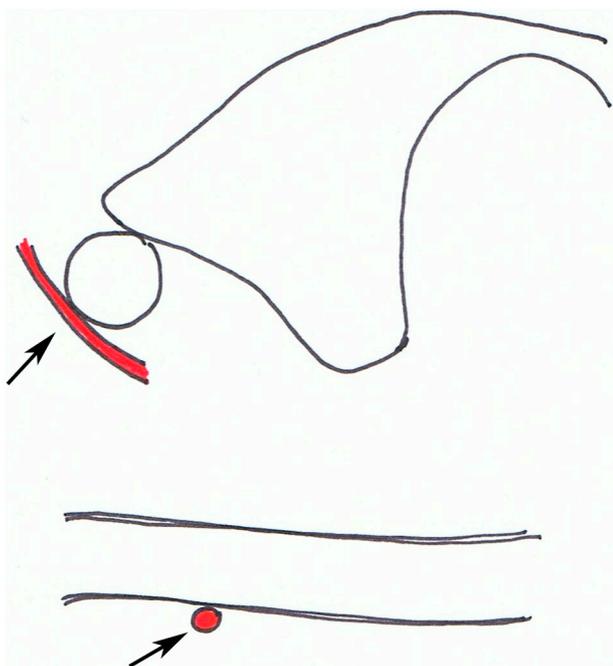


Fig. 14. Inferior thyroid artery (arrow) represented running posteriorly to the common carotid artery in the transverse and longitudinal planes.

which might mimic a hypoechoic thyroid nodule or a heterogeneity area; these can be easily ruled out, by either applying compression or moving the transducer laterally and/or to the longitudinal plane, and perceiving the subsequent disappearance of the “hypoechoic” area [9] (Figs. 5 and 6).

The anterior and/or internal jugular veins are often asymmetric (Figs. 7 and 8). These are normal variants, lacking pathologic significance.

### 2.2. Longitudinal plane

In the midline, starting superficially and moving inwards, we find the skin, subcutaneous fat, strap muscles, isthmus, the thyroid and cricoid cartilages (superiorly), and the first tracheal rings (inferiorly). The thyroid isthmus is often found anteriorly to the first tracheal rings (Fig. 9). Laterally (Fig. 10), below the cutaneous and muscular structures, we will find the lateral lobes of the thyroid gland. Careful scanning must be performed to guarantee the inclusion of the entire gland within the scanned area, in both the transversal and longitudinal planes. In the longitudinal plane, observing an angular shape at the upper and lower extremities of the lateral lobes, guarantees the inclusion of the entire lobe [8,9].

Swallowing can also improve the visualization of the lower pole of the lateral lobes.



Fig. 15. Thyroid gland agenesis in the normal location.

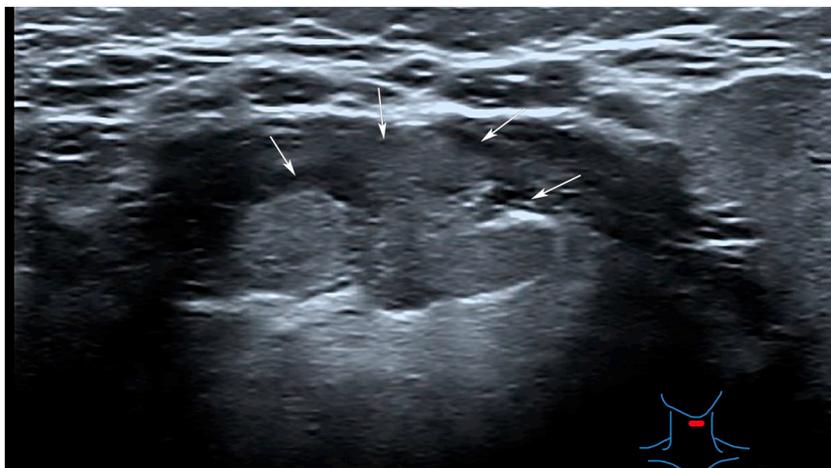


Fig. 16. Same patient as Fig. 15 — ultrasound image of the floor of the mouth, revealing the presence of thyroid glandular tissue (arrows).

### 2.3. Vascular and nerve structure assessment [15,16]

The paired superior and inferior thyroid arteries supply the thyroid gland.

The superior thyroid arteries are the first branches of the external carotid arteries. We can follow them longitudinally, with colour Doppler, from their origin to the upper pole of the lateral lobes, where they split into terminal branches to supply the gland (Figs. 11 and 12).

The inferior thyroid arteries arise from the thyrocervical trunk. They are easily perceived with Doppler/ultrasound due to their unique transversal course behind the common carotid arteries (Figs. 13 and 14).

An inconstant thyroid artery (of Neubauer) might be present [15].

Using colour Doppler, the normal thyroid parenchyma is scarcely vascularized, contrasting with thyroiditis' *thyroid inferno* hyper-vascularization. A wide range of Doppler patterns can be found between the normal and pathologic extremes [10].

A prominent venous network is usually seen peripherally and anteriorly. It drains toward the paired superior, medial, and inferior thyroid veins [15].

The recurrent laryngeal nerves, together with the inferior thyroid vessels, can be found within the tracheoesophageal groove, and adjacent to the trachea, on the left and right sides of the neck, respectively [17].



Fig. 17. Same patient as Fig. 16 — ct axial image of the floor of the mouth. Arrows indicate the ectopic thyroid tissue.

### 3. Anatomical variants

Anatomical variants of the thyroid gland are relatively frequent overall, and are related to the gland's embryologic development [8,16].

We can find accessory lobes or accessory glandular tissue not connected to the thyroid parenchyma superiorly (pyramidal lobe and thyroglossal duct or remnants), inferiorly (thyrothymic rests), external, and posteriorly (Zuckerkindl lobe or tubercle) to the gland. Additionally, part of, or even the entire gland, might not be found in the usual location (ectopic tissue).

Occasionally, thymus or parathyroid glands can be found in an intra-thyroidal location.

#### 3.1. Agenesis/hemi-agenesis

These are rare anatomical variants, thought to be related to a descent disturbance and/or a lobulation defect. When not found (partially or entirely) in the usual location, a possibly ectopic thyroid gland should be searched for with ultrasound, along the entire path of the thyroglossal duct. Occasionally, lingual thyroid is the only thyroid tissue present (Figs. 15–17). The left lobe is more frequently absent than the right [18].

Hemi-agenesis (Fig. 18) is thus easily recognized in an ultrasound examination when, in the absence of previous surgery, one lobe and/or the isthmus are not identified.

#### 3.2. Pyramidal lobe

The pyramidal lobe is an inconstant protrusion located on the superior border of the gland, also known as Lalouette's pyramid [15]. On the transverse section, the base of the pyramidal lobe may simulate an isthmic nodule. It can be easily ruled out by rotating the probe to the longitudinal plane and spotting the pyramidal shape. A normal

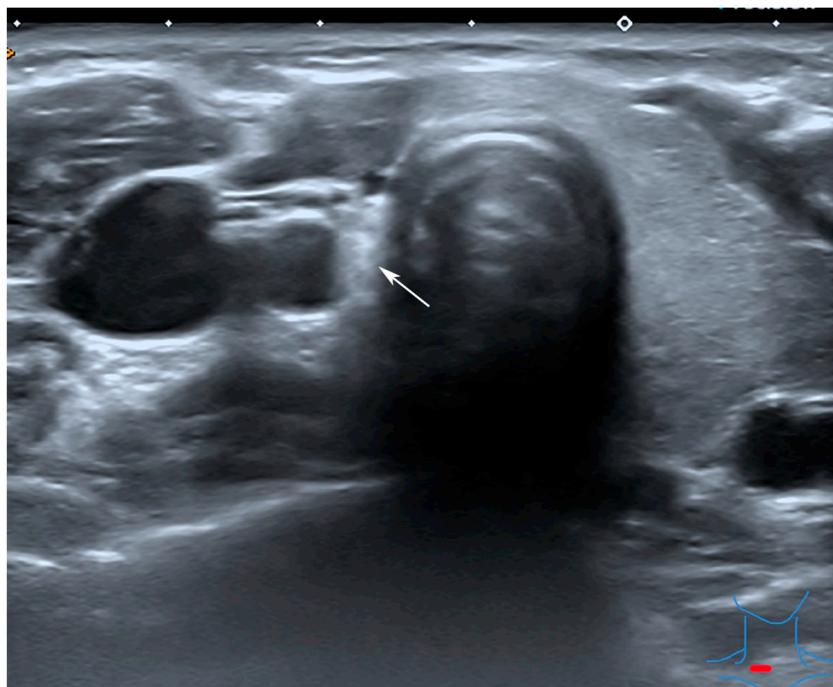


Fig. 18. Right thyroid lobe hemi-agenesis.

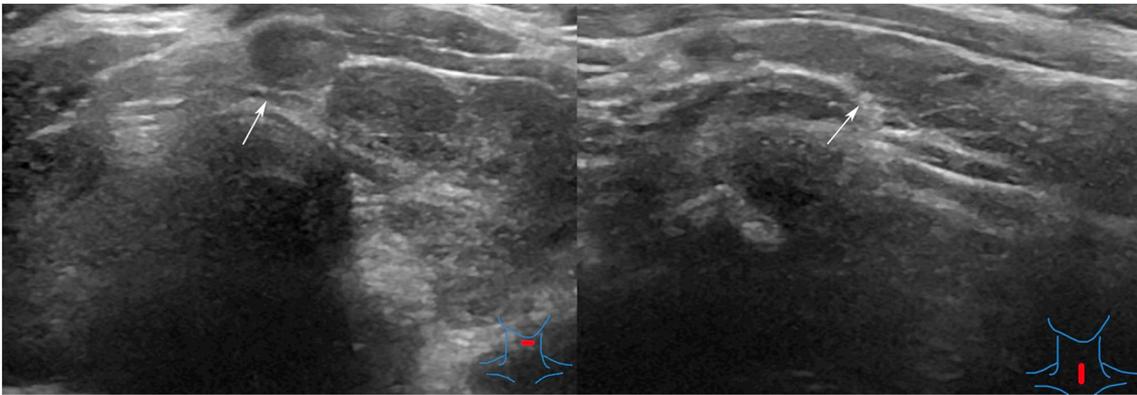


Fig. 19. Pyramidal lobe (arrow) — transverse plane (left) — pyramidal lobe simulates a nodule; longitudinal plane (right) — pyramidal shape can be assessed.

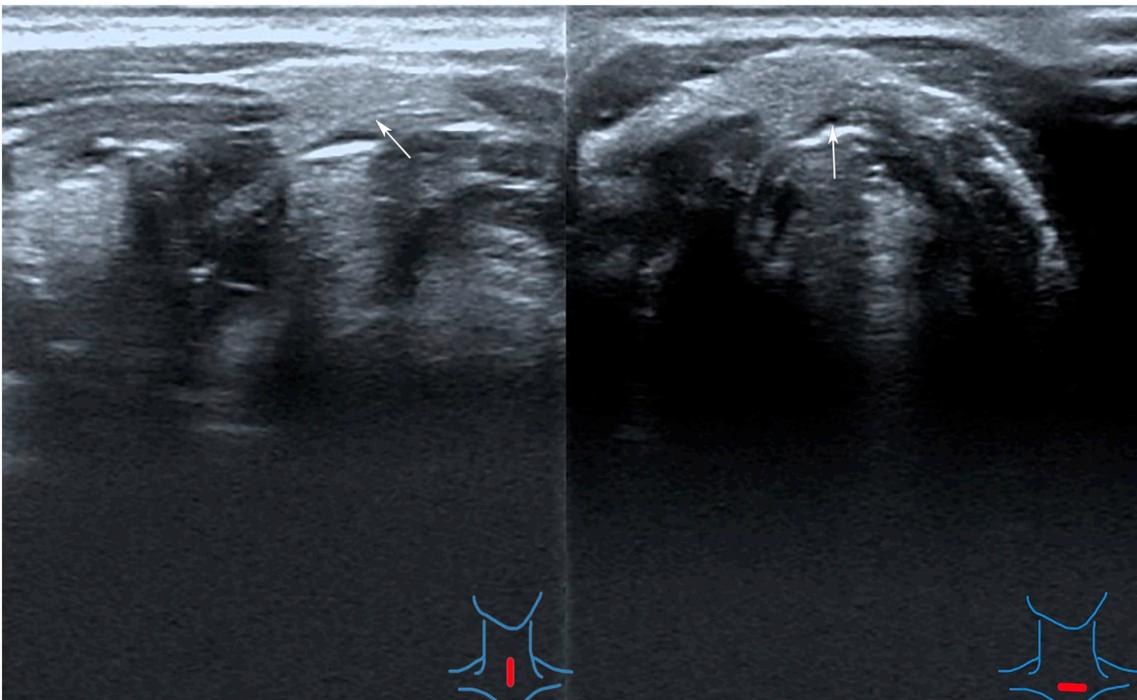


Fig. 20. Ectopic thyroid tissue remnants (arrows), along the thyroglossal duct tract.

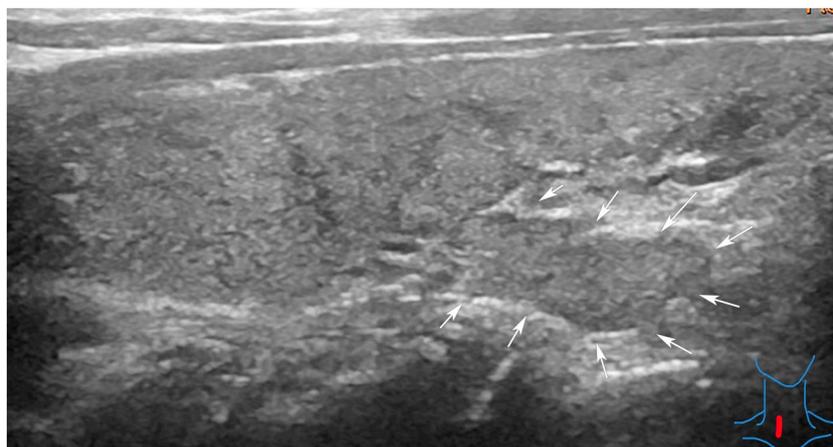


Fig. 21. Ultrasound lateral lobe longitudinal plane — Zuckerkandl tubercle (arrows).



Fig. 22. Same patient as in Fig. 21. Reformatted para sagittal CT — Zuckerkandl tubercle (arrows).

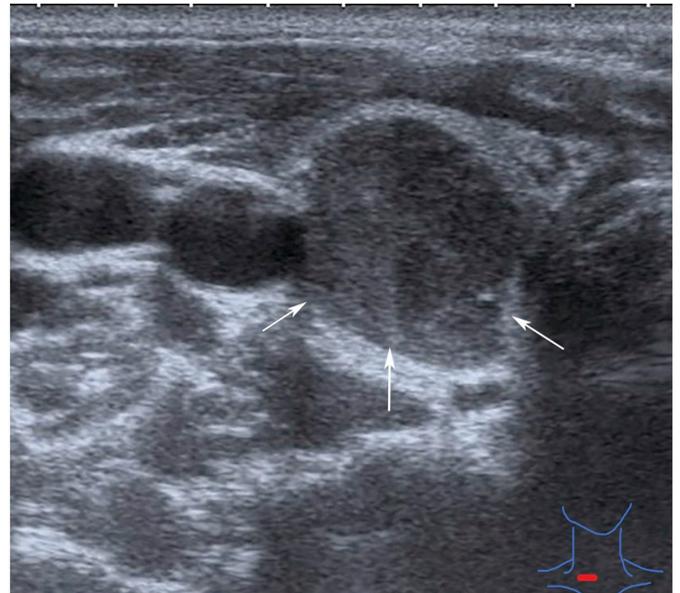


Fig. 24. Histology-proven parathyroid adenoma (arrow), located posteriorly to the thyroid, compressing thyroid parenchyma, and mimicking a thyroid nodule—transverse plane.

pyramidal lobe should also have the same echogenicity and vascularization as the adjacent thyroid parenchyma [19] (Fig. 19).

The correct identification of this structure is important for several reasons: to start with, it is relatively frequent and might be present in up to 70% of individuals [16]. Ryu et al. [19] found a pyramidal lobe in 81/135 patients that underwent thyroidectomy; secondly, it should not

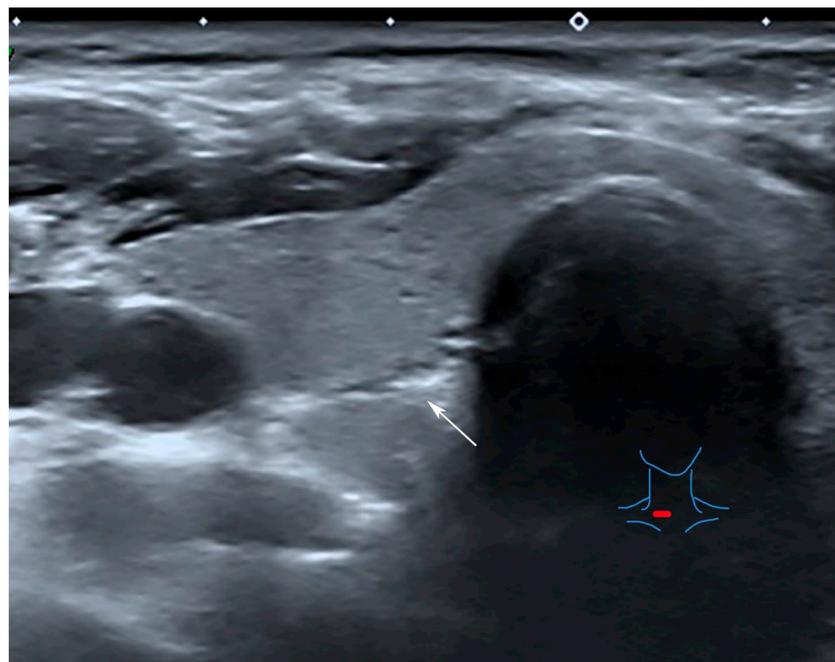


Fig. 23. Ultrasonography, transverse plane: hyperechoic septum simulating a nodule (arrow).

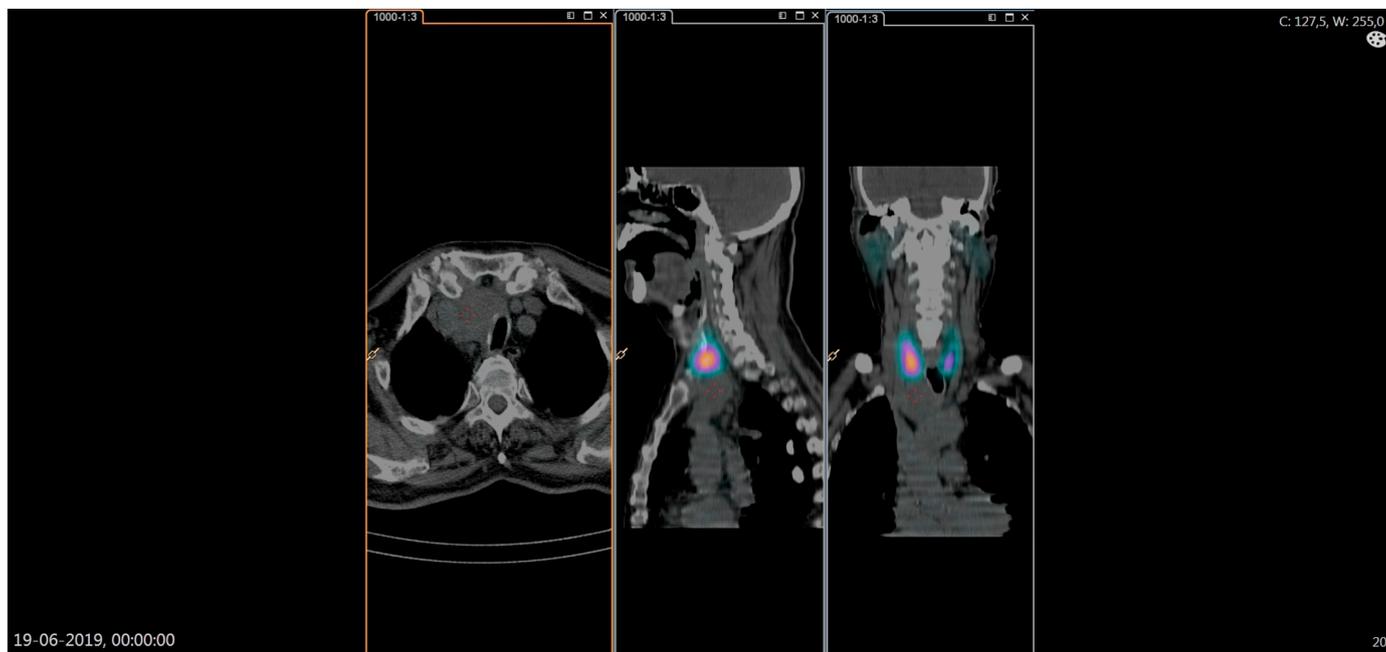


Fig. 25. 99mTc-pertechnetate scintigraphy (SPECT-CT) in a 75-year-old male patient with a right paratracheal mass adjacent to the lower right thyroid lobe — Thyroid: normal uptake; Mass: no uptake.

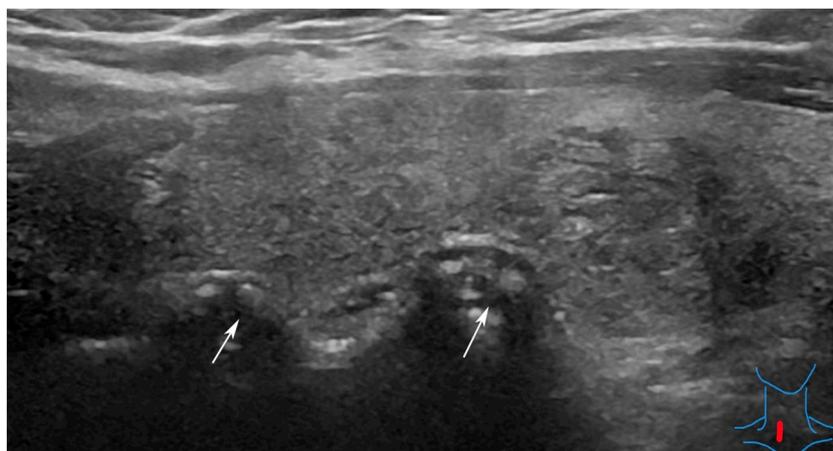


Fig. 26. Longitudinal b-mode ultrasound; osteophytes mimicking calcified thyroid nodules (arrows).

be mistaken for a nodule; finally, in the event of a concomitant thyroid carcinoma, surgeons should be informed of its presence to ensure that no residual thyroid tissue is left behind, as it could become a recurrent site later on.

### 3.3. Ectopic thyroid/thyroglossal duct cyst

Above the thyroid gland and as far as the tongue base, but not attached to the glandular parenchyma, we can find ectopic thyroid tissue (or nodules) along the tract of the thyroglossal duct [16,20] (Fig. 20).

### 3.4. Zuckerkandl tubercle (or lobe)

It is a normal posterior extension of the thyroid parenchyma, which is also composed of normal thyroid tissue, although occasionally it can appear to be a nodule. The tubercle can have different sizes. It is thought to originate from the embryologic development fusion of lateral anlagen to the median anlage. In images, it is the part of the thyroid that extends posteriorly to the tracheoesophageal groove. It is important as an anatomical landmark for the recurrent laryngeal nerves and the superior parathyroid gland. Again, it should not be mistaken for

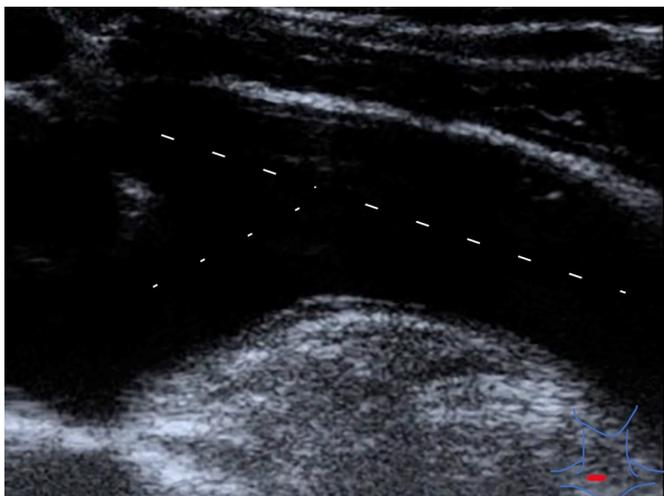


Fig. 27. Normal brachiocephalic artery bifurcation: the “y sign”; transverse ultrasound image.

a nodule [21] (Figs. 21 and 22).

3.5. Septum

A hyperechogenic septum is often found posteriorly in thyroid lobes. It should not be referred to as a nodule or mistaken for a parathyroid gland, nor should it be labeled an incomplete halo of an in-existent nodule. Ultrasound-scanning on a different plane will solve any possible doubts [9] (Fig. 23).

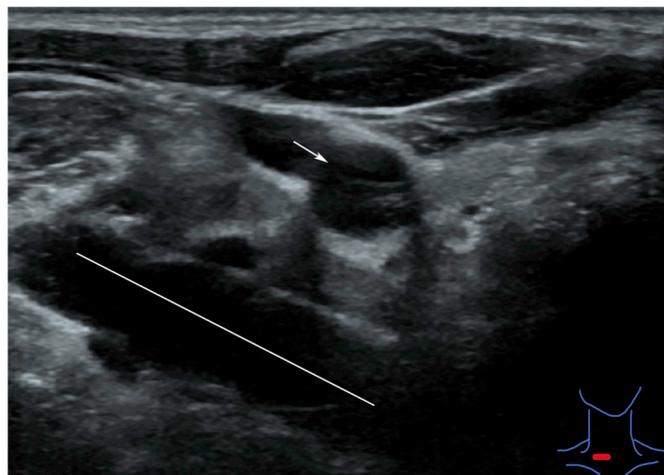


Fig. 29. Transverse ultrasound failing to demonstrate the presence of the y sign: the presence of an arteria lusoria (and a possible non-recurrent laryngeal nerve) is suspected.

3.6. Parathyroid glands

The parathyroid glands are located posteriorly to the upper and lower poles of thyroid lateral lobes. When normal, they are usually not identifiable.

When enlarged, these structures display as hypoechoic nodules, may compress the adjacent anterior thyroid parenchyma and can erroneously be classified as thyroid nodules. Correlation with clinical and laboratory data is crucial (Fig. 24).

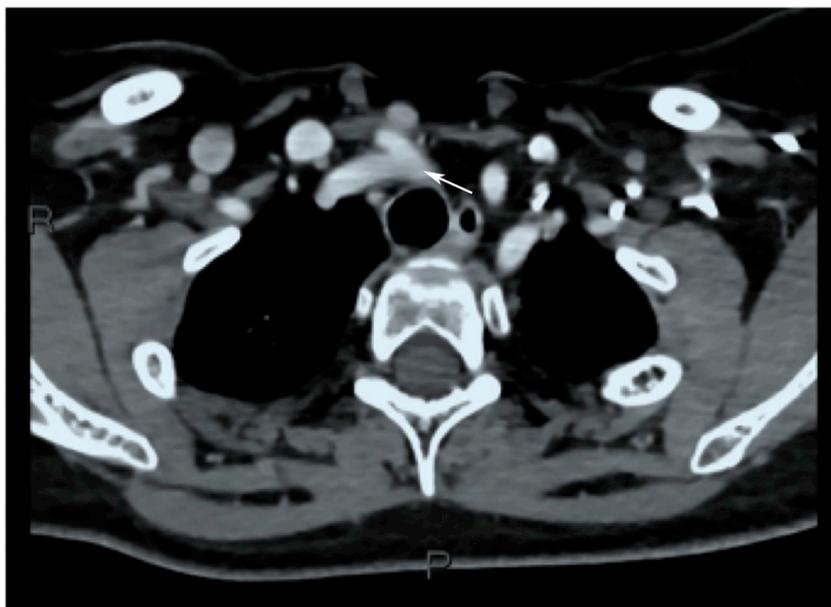


Fig. 28. Normal brachiocephalic artery bifurcation: the “y sign”; axial CT.



**Fig. 30.** Coronal CT reformatting, of the same patient as in Fig. 28, revealing the aberrant origin of the right subclavian artery (arteria lusoria — arrow).

Double-tracer parathyroid scintigraphy (99mTc-sestamibi or 99mTc-tetrofosmin — 99mTc-pertechnetate or 123I) may be useful in these situations, by allowing the distinction of thyroid and parathyroid tissue, and has already been applied successfully in patients with

hyperparathyroidism. Dual-phase parathyroid scintigraphy is useful in patients with primary and secondary hyperparathyroidism who could benefit from parathyroid surgery (conventional and minimal invasive), being indicated to locate hyperfunctioning parathyroid gland(s) before first surgery and also to detect recurrent or persistent disease [22] (Fig. 25).

### 3.7. Osteophytes

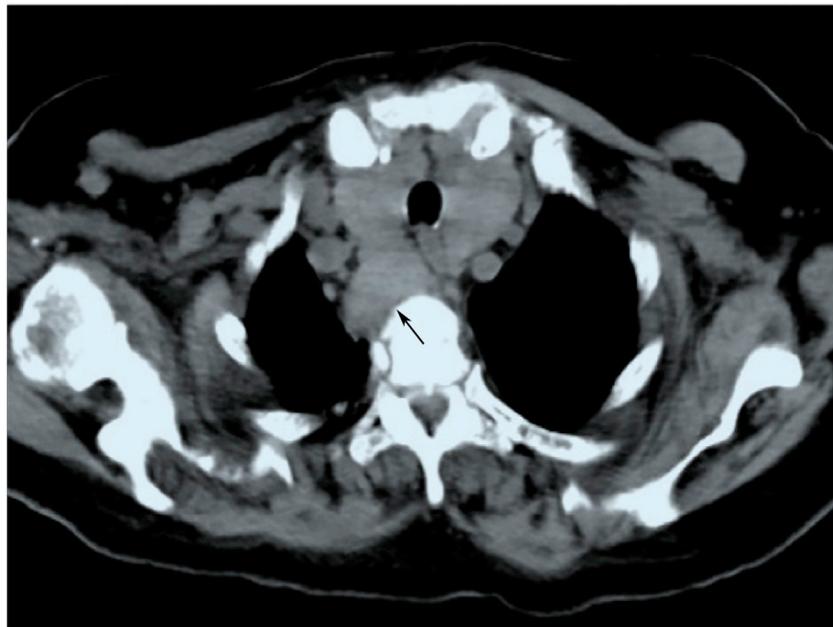
Other structures, such as osteophytes, can be found posterior to the lateral lobes of the thyroid gland and misdiagnosed as calcified nodules (Fig. 26). These can be easily ruled-out with a neck X-ray.

### 3.8. Recurrent laryngeal nerves

The possible existence of a non-recurrent laryngeal nerve is clinically relevant in the setting of a pre-operative evaluation, as its presence increases the risk of vocal cord paralysis as a surgery complication. It is associated with an aberrant right subclavian artery. The presence of a normal right subclavian artery can be easily explored with ultrasound [17]. The finding of the normal bifurcation of the brachiocephalic artery, the “y sign” [23], is easily accomplished and can rule-out that rare anatomical variant (Figs. 27, 28, 29 and 30).

### 3.9. Thyroid remnants in the thyrothymic tract

Thyroid tissue can also be found as an inferior prolongation of the gland, most commonly attached to the inferior pole, but sometimes isolated in the upper mediastinum (Fig. 31). It can be an origin site of goiter, namely mediastinal goiter, mistaken for parathyroid adenomas, or be the source of a post-surgical recurrence [24].



**Fig. 31.** Inferior (mediastinal) extension of thyroid parenchyma (arrow).

#### 4. Concluding remarks

Knowledge of normal cervical ultrasound anatomy is crucial to avoid diagnostic pitfalls and potential complications in ultrasound-guided invasive techniques.

Identification and routine description of anatomical variants has strong clinical/pre-surgical relevance.

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