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Thyroid ultrasound — a piece of cake?

Zrobić USG tarczycy każdy może, trochę lepiej lub trochę gorzej

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Abstract
The introduction of sonographic imaging has revolutionized the diagnostics of thyroid pathologies. Nowadays, thyroid ultrasound examination has become an essential part of routine thyroid gland evaluation. Although one of the greatest advantages of this examination lies in its simplicity, it requires a solid theoretical background, as well as a lot of experience for the examiner to become fluent in adequate interpretation of its results. The aim of this summary is to present a review of the most important aspects of both the technique and interpretation of thyroid ultrasound pictures with regard to the most common difficulties a thyroid sonographer may come across in everyday practice. **(Pol J Endocrinol 2010; 61 (3): 330–344)**

Key words: *endocrine diagnostic techniques, ultrasonography, thyroid diseases, diagnostic errors*

Streszczenie
Wprowadzenie badań sonograficznych zrewolucjonizowało diagnostykę chorób tarczycy. Obecnie badanie ultrasonograficzne tarczycy jest stałym elementem rutynowego badania gruczołu tarczowego. Jedną z największych zalet tego badania jest łatwość jego przeprowadzania, jednak do odpowiedniej interpretacji jego wyników potrzebna jest rzetelna teoretyczna wiedza oraz duże doświadczenie. Celem niniejszej pracy było przedstawienie najważniejszych aspektów techniki i interpretacji obrazu ultrasonograficznego tarczycy z uwzględnieniem najczęstszych trudności, jakie osoba przeprowadzająca to badanie może napotkać w codziennej praktyce.
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Słowa kluczowe: *diagnostyka endokrynologiczna, ultrasonografia, choroby tarczycy, pomyłki diagnostyczne*

„You see only what you look for,
you recognise only what you know."

Merril C. Sosman

Introduction

Recent years have brought widespread use of ultrasound techniques in diagnostics of thyroid gland pathologies. The technical development of sonographic imaging has converged together with its increasing accessibility. Therefore, due to its numerous advantages, thyroid ultrasound examination has evolved from a method reserved for experimental studies, used only to support other diagnostic means, to an essential part of, and a gold standard in, the diagnostics of thyroid diseases. It allows repeatable, real-time, and non-invasive assessment of the thyroid morphology. It does not expose patients to radioactive isotopes or Roentgen radiation, it is quick and comfortable for patients, and so can be repeated without any harm and be performed even in children or pregnant women. The key to its application in endocrine diagnostics is its high sensitivity in the detection of thyroid pathologies. Thus, thyroid ultrasound examination is nowadays widely applied not only for diagnosis, but also in the follow-up of both pharmacological and surgical treatment of thyroid diseases. Additionally, ultrasound assessment of thyroid volume precedes radioiodine treatment in patients with hyperthyroidism and is helpful in accurate calculation of the dose of radioisotope. It is also a quick, easy, and low-cost examination; hence it has found application in population-based screening studies. The recent employment of novel techniques, including Doppler imaging, virtual convex, 3D imaging, contrast-enhanced ultrasound, and sonoelastography, has further increased its diagnostic value. However, the greatest advantage of thyroid ultrasound examination is the possibility to visualize the tip of the needle during fine-needle aspiration biopsies, which allows a precise biopsy of even small thyroid focal lesions, and so has revolutionized the diagnostics of thyroid nodular disease. It, therefore, raises no doubts as to why the role of the

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thyroid ultrasound scanner is now compared to the role of the stethoscope for a cardiologist [1]

Despite its unquestionable advantages, this examination also has several limitations. The ultrasound waves do not penetrate through calcified structures, so the sonographic assessment of deep retrosternal goiter or nodules containing calcifications is largely limited. Moreover, ultrasound examination is a typical morphological one, so using it to draw conclusions pertaining to thyroid hormonal function is unwarranted. Although some of the features of thyroid nodule detected exclusively on the basis of ultrasound examination augment the suspicion of a malignant lesion, the differentiation between a benign and a malignant lesion cannot be performed. Finally, it must be remembered how crucial the quality of the equipment used for the examination and the experience of the sonographer are for the credibility and reproducibility of this examination. Thus, the awareness of both the advantages and limitations of this examination is the key to a successful interpretation of ultrasound pictures.

The aim of the paper is to present the current and most important facts concerning the technique and the interpretation of thyroid ultrasound examination, especially with regard to the most frequent difficulties a thyroid sonographer may come across in everyday practice.

Thyroid topography — important facts

The thyroid is an unpaired endocrine organ located superficially in the lower part of the neck. Normally, it consists of two lobes, right and left, connected by an isthmus (Fig. 1). The thyroid gland is separated from the hyperechogenic skin only by a thin hypoechogenic layer of muscles (sternohyoid, sternothyroid, and, most laterally located, sternocleidomastoid muscle), which constitute the anterior wall of the thyroid. The large vessels of the neck — common carotid artery and jugular vein — are situated on the lateral wall of the thyroid gland. On the posterolateral wall, the long muscle of the neck is located and is especially easily seen in thin patients and men. Both thyroid lobes are located laterally towards the trachea. The esophagus, frequently erroneously described as the thyroid nodule, is placed on the posteromedial wall of the thyroid, most often on the left side. It is usually oval or round and approximately 10 mm in size. It can be easily distinguished from a thyroid lesion by asking the patient to swallow, which allows one to observe concentric clamping of its volume and hyperechogenic saliva inside.

Technique of the examination

During a thyroid ultrasound examination, the patient lies in a supine position, with the head tilted backwards. The sonographer holds the probe like a pen and places it in the lower part of the neck. It is particularly important to provide constant and accurate adherence of the probe to the examined area, which should be well coated with ultrasound gel.

There are also some important facts regarding the technical parameters of the equipment used for thyroid examination which have to be kept in mind. The frequency of ultrasound waves is inversely correlated to their length and ability to penetrate the anatomical structures. Therefore, ultrasound scanners equipped with probes of high frequency allow high resolution imaging of organs located rather superficially. The minimal requirements for thyroid examination include a linear probe of frequency at least 7.5 MHz, but currently those of higher frequency, up to 15 MHz, have become more widely used [2].

Routinely, the thyroid is examined in two main plains: transverse and longitudinal (Fig. 1). To visualize the transverse section of the thyroid lobe, the probe should be placed square to its long axis. First, the whole thyroid is scanned, from the upper to the lower pole, in search of any abnormalities. Next, the thyroid is typically visualized in the longitudinal section. This is attained by tilting the probe by about 90° and placing it in parallel to the sternocleidomastoid muscle to visualize both poles of the lobe. This should be performed for each thyroid lobe separately.

Description of the examination

The result of the thyroid ultrasound examination should describe primarily the location of the gland. Usually, if it is not specified in the final report from the examination, it can be assumed that the position is normal. Sometimes, in cases of a large goiter, if visualization of the lower poles of the lobes is impossible, such a thyroid should be described as partially retrosternal or intrathoracic. In such cases, positioning the probe diagonally is helpful in visualization of the lowest part of the gland located below the suprasternal notch. However, if no thyroid tissue can be visualized in a typical cervical location and there is no history of thyroidectomy, it raises suspicion of thyroid dysgenesis and indicates the need for a search for ectopic thyroid.

A key part of thyroid ultrasound examination is the assessment of thyroid size by measuring three dimen-

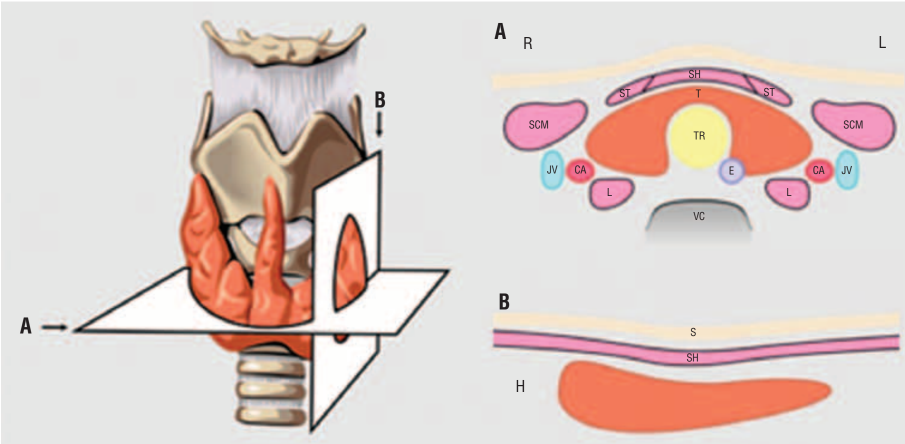

Figure 1. *Transverse (**A**) and longitudinal (**B**) section of the thyroid. CA —carotid artery; E — esophagus; H — head direction; JV — jugular vein; L — long muscle of the neck; S — skin; SCM — sternocleidomastoid muscle; SH — sternohyoid muscle; ST — sternothyroid muscle; T — thyroid; TR — trachea; VC — vertebral column*

Rycina 1. *Przekrój poprzeczny (**A**) i podłużny (**B**) tarczycy. CA — tętnica szyjna; E — przełyk; H — kierunek dogłowowy; JV — żyła szyjna; L — mięsień długi szyi; S — skóra; SCM — mięsień mostkowo-obojczykowo-sutkowy; SH — mięsień mostkowo-gnykowy; ST — mięsień mostkowo-tarczowy; T — tarczyca; TR — tchawica; VC — kręgosłup*

sions of each lobe. This allows an accurate estimation of the volume of the gland. The thyroid lobe has an ellipsoid shape, with the largest dimension in its central part, more or less at the level of the isthmus. The thyroid lobe volume in ml (cm^3) is measured with the use of elliptical shape volume formula:

$$a \times b \times c \times \frac{\pi}{6} \text{ or, in practice, } a \times b \times c \times \frac{1}{2},$$

where: a — width, b — depth and c — length of the thyroid lobe, expressed [3]. The width of the thyroid lobe is the distance between the lateral and medial wall of the thyroid lobe and the depth is the distance between the anterior and posterior wall of the thyroid lobe, while the length is measured from the upper to the lower pole of the thyroid lobe. It is important to perform the assessment of width and depth of the thyroid lobe at the level of the isthmus to prevent underestimation of thyroid size in case of measuring close to the poles. For the same reasons, the estimation of the length of the thyroid lobe ought to be performed in the middle part of the gland. The width and the depth of the thyroid lobe are assessed in the transverse section while the length is measured in the longitudinal plain. To provide accurate measurement, the ultrasound probe should be placed square, not slantwise, to the skin. Modern ultrasound scanners are often equipped with software designed to calculate thyroid volume automatically after three dimensions are measured. It is important to assess the volume of the thyroid for each lobe separately because thyroid asymmetry is common. The right lobe is usually bigger, more elongated, and more often undergoes nodular changes [4–6]. The total volume of the thyroid is, therefore, the sum of volumes of both lobes. In calculating thyroid volume, the size of the isthmus and additional thyroid tissue, like the pyramidal lobe or accessory thyroid gland, is not taken into account. The WHO (World Health Organisation) recommends that normative values for thyroid volume are 18 ml for women and 25 ml for men. For children, thyroid volume is normalised according to age and gender. What is important, there is no lower reference range for normal thyroid volume. As long as it is sufficient to provide adequate hormonal production, the thyroid is considered to be of normal size.

One of the most important parts of a thyroid ultrasound examination, often omitted by radiologists, however crucial for endocrine diagnostics, is the description of thyroid parenchymal echogenicity. Thyroid echogenicity can be homogeneous (normal) or heterogeneous. In the assessment of thyroid echogenicity, the most important element is to compare it to the echogenicity of the surrounding muscles, which are normally hypoechogenic in comparison to thyroid tissue. The border between the layer of muscles and the thyroid should also be easy to mark. Such a thyroid is called normoechogenic. If thyroid echogenicity becomes similar to that of muscles, it is named hypoechogenic (Fig. 2). In describing thyroid echogenicity, the presence of additional findings such as calcifications or fibrosis should be notified. Calcifications on thyroid ultrasound are visible as highly hyperechogenic structures of different size, causing acoustic shadows, which makes the assessment of the tissues located dorsally to the calcification extremely difficult (Fig. 3). Therefore, especially large calcifications or nodules with a calcified capsule are quite difficult to assess. On the other hand, hyperechogenic,

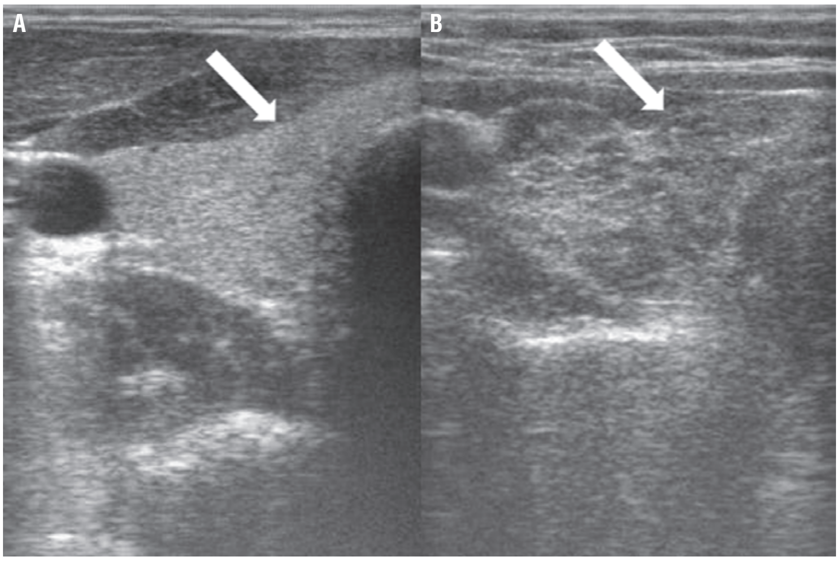

Figure 2. *A. Normal thyroid. Note homogeneous echogenicity and well-defined borders.* ***B****. Thyroid of decreased and heterogeneous echogenicity in a patient with autoimmune thyroid disease. Note ill-defined borders between the thyroid and muscles*

Rycina 2. *A. Prawidłowa tarczyca. Należy zwrócić uwagę na jednorodną echogeniczność i wyraźne granice narządu.* ***B****. Tarczyca o obniżonej i niejednorodnej echogeniczności u pacjenta z autoimmunologiczną chorobą tarczycy. Należy zwrócić uwagę na niewyraźne granice między tarczycą a mięśniami*

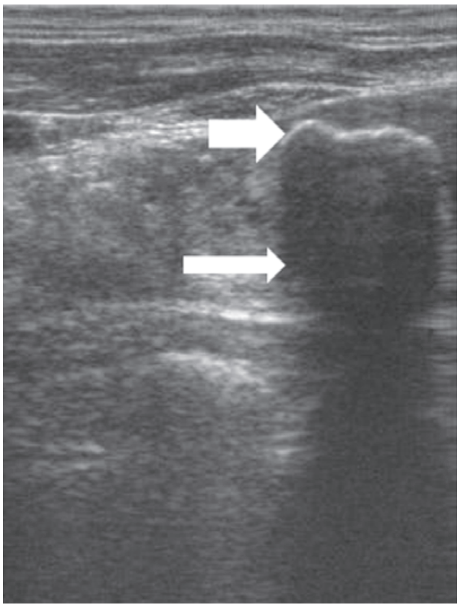

Figure 3. *Acoustic shadow (thin arrow) located dorsally to the massive calcification (thick arrow)*

Rycina 3. *Cień akustyczny (cieńsza strzałka) zlokalizowany grzbietowo w stosunku do masywnego zwapnienia (grubsza strzałka)*

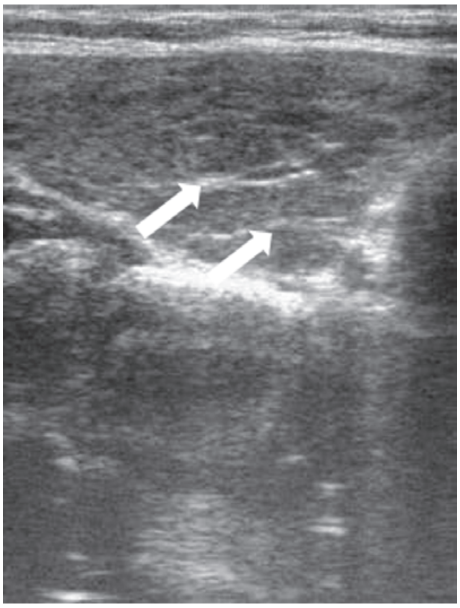

Figure 4. *Hyperechogenic lines in thyroid parenchyma, indicating the process of fibrosis, typical for late phase of Hashimoto's thyroiditis or status after radioiodine treatment*

Rycina 4. *Hiperechogeniczne pasma w miąższu tarczycy wskazujące na proces włóknienia typowy dla późnej fazy choroby Hashimoto lub stanu po leczeniu jodem promieniotwórczym*

linear changes in the thyroid parenchyma might indicate fibrosis (Fig. 4).

In some cases, evaluation of thyroid parenchyma or nodule vascularisation is helpful. At present, most ultrasound machines are equipped with Doppler imaging. Visualization of blood flow is useful in the differentiation between cystic lesions and vessels (Fig. 5). Additionally, increased or decreased thyroid vascularisation might indicate thyroid functional status, as well as give clues helpful for the diagnosis of the type or phase of autoimmune thyroid disease (Fig. 6). It has also been observed that the type of blood flow is associated with the risk of malignancy of thyroid nodules, or met-

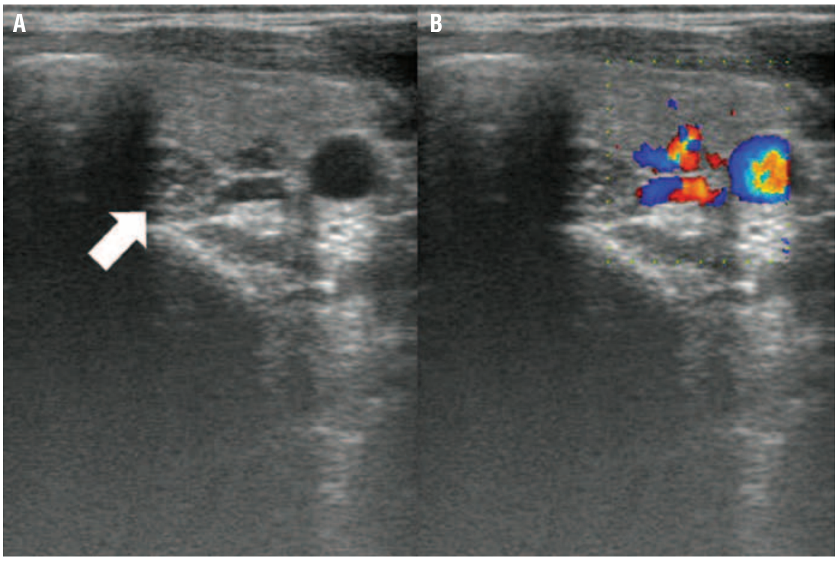

Figure 5. *Differentiation of cystic lesions and vessels using the Doppler colour flow imaging. An arrow indicates the esophagus. The blood flow inside the lesions confirms the presence of normal vessels*

Rycina 5. *Różnicowanie między torbielami a naczyniami krwionośnymi w badaniu z wykorzystaniem techniki Dopplera z kodowaniem przepływów kolorem. Strzałka wskazuje przełyk. Przepływ krwi wewnątrz zmiany potwierdza obecność prawidłowych naczyń*

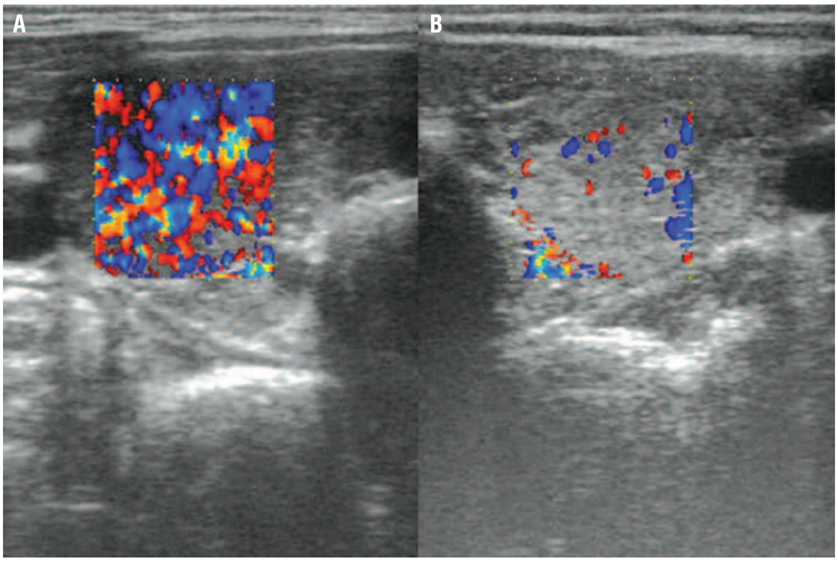

Figure 6. ***A.*** *Markedly increased thyroid blood flow in Graves' disease.* ***B.*** *Decreased thyroid vascularization in Hashimoto's thyroiditis*

Rycina 6. ***A.*** *Znacznie zwiększony przepływ krwi w tarczycy w przebiegu choroby Gravesa-Basedowa.* ***B.*** *Zmniejszone unaczynienie tarczycy w chorobie Hashimoto*

astatic character of lymph nodes. Thus, the presence of increased central vascularisation is indicative of more suspicious lesions than those characterized by peripheral blood flow [7].

If any thyroid focal lesion is detected, it should be described with regard to its location (upper pole, central part, or lower pole; lateral, medial, anterior, or posterior wall) and characteristics. The latter should involve the number of lesions (solitary nodule or multinodular goiter), size (three dimensions), structure (cystic, solid, mixed), and echogenicity (anechogenic, hypoechogenic, isoechogenic, hyperechogenic). The echogenicity of thyroid focal lesions is described in relation to the surrounding thyroid parenchyma. Anechogenic lesions are predominantly simple cysts, containing serous, or serosanguineous liquid or colloid. They can be emptied by fine needle aspiration. Simple cysts are often oval or round, with regular borders and characteristic posterior

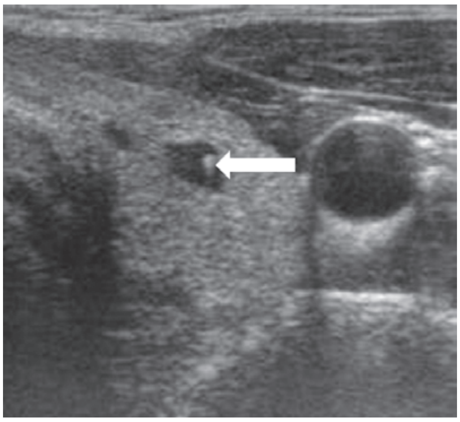

Figure 7. *A comet-tail artefact in a very dense colloid thyroid cyst*
Rycina 7. *Artefakt w kształcie ogona komety w torbieli zawierającej bardzo gęsty koloid*

wall enhancement. An anechogenic lesion may be differentiated from a vessel with Doppler imaging showing blood flow inside the vessel, which is not seen inside the cyst (Fig. 5). Cysts may also be multi-chambered, containing numerous septa or even calcifications. Serous cysts are usually completely anechogenic. If the content of a cyst is markedly dense, a comet-tail artefact might appear (Fig. 7), which is a hyperechogenic spot inside a cyst, resembling a comet in shape, often accompanying colloid cysts of high density[8]. Their presence usually predicts difficulties in the aspiration of the cyst and requires the use of a needle of a larger size. The obtained content is often white or yellowish and has the consistency of thick glue. Haemorrhagic cysts are another type of cyst. They may contain tiny echoes inside, and their appearance depends on the time of formation. "Young" cysts present as lesions with regularly scattered tiny echoes inside, while "older" ones can be anechogenic, or may contain sediment of old morphotic elements of blood in the dorsal part of the cyst (Fig. 8). The colour of the aspirated fluid ranges from dark yellow to brown, which is why such lesions are also sometimes called chocolate cysts.

Solid lesions are another type of focal changes that can be found in the thyroid. A solid nodule is called hypoechogenic when it shows a relatively decreased echogenicity with regard to the normal thyroid parenchyma, isoechogenic (when showing a similar pattern of echogenicity as a normal thyroid), or hyperechogenic (when a nodule shows a relatively increased echogenicity pattern with regard to normal thyroid tissue). Isoechogenic lesions are the most difficult to notice because of the similarity of their texture to the surrounding thyroid tissue. In some cases, they can only be seen due to a halo formed by a hypoechogenic capsule, which circumscribes the lesion (Fig. 9). A hypoechogenic pattern of a nodule was shown to be associated with higher risk of malignancy [9]. Some nodules also present a so-

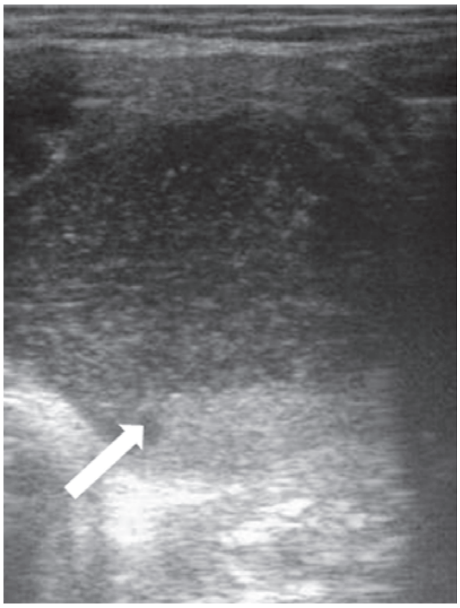

Figure 8. *A large haemorrhagic thyroid cyst, containing sediment of old morphotic elements of blood in the dorsal part of the cyst*
Rycina 8. *Duża krwotoczna torbiel tarczycy, zawierająca w części grzbietowej osad ze starych elementów morfotycznych krwi*

called spongiform appearance, which is defined as an aggregation of multiple microcystic components in more than 50% of the volume of the nodule [10] (Fig. 10).

The shape of a nodule, another feature that needs to be described, can be categorized into several main types: round (when all diameters of the nodule are equal), oval (when the transverse diameter is larger than the anteroposterior diameter), taller than wide (when the anteroposterior diameter is larger than transverse diameter), or irregular [10]. Of these, the taller than wide profile is suggestive of thyroid cancer more than any other constellation [9]. It is also important to include the character of the nodule's margins in the final report, which can be well-defined and smooth or ill-defined. The former is more typical for benign lesions while ill-defined borders may indicate a malignant character.

Finally, it is worth mentioning the presence and the type of calcifications in thyroid lesions. Microcalcifications of a diameter below 2 mm, which are tiny punctate hyperechogenic foci, with or without posterior shadowing, are characteristic of differentiated thyroid cancer, while macrocalcifications are more typical for medullary cancer. In particular, irregularly scattered calcifications are suspected of accompanying thyroid cancer. Rim calcifications are another type found in the thyroid: a curvilinear calcification on the margin of a nodule, also called an egg-shell calcification [10] (Fig. 11).

A novel ultrasound technique which is increasingly used is sonoelastography. It is widely known that the firm or hard consistency of nodules on palpation is as-

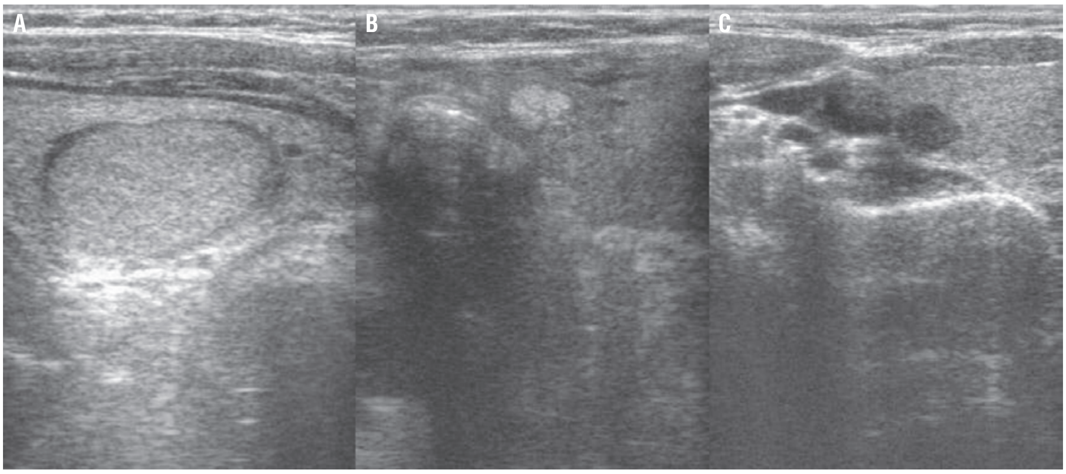

Figure 9. *A. Isoechogenic nodule with hypoechogenic capsule.* ***B.*** *Hyperechogenic nodule.* ***C.*** *Hypoechogenic nodule*

Rycina 9. ***A.*** *Ognisko izoechogeniczne z hypoechogeniczną otoczką.* ***B****. Ognisko hyperechogeniczne.* ***C.*** *Ognisko hypoechogeniczne*

Figure 10. *A nodule with so-called spongiform appearance*

Rycina 10. *Ognisko o tak zwanym utkaniu gąbczastym*

sociated with an increased risk of malignancy [11–13]. However, this clinical parameter is highly subjective and dependent on the experience of the examiner. Sonoelastography is a technique used to provide an objective estimation of tissue stiffness by measuring the degree of distortion under the application of an external force. The first studies have demonstrated its high sensitivity and specificity in detecting malignant thyroid lesions. Thus, decreased elasticity of lesions should raise the suspicion of thyroid malignancy [14]. Figure 12 presents a nodule of mixed character, containing regions of both high and markedly decreased elasticity. Sonoelastography might also be helpful in choosing particular suspected nodules in multinodular goiter, as well as the region of the thyroid lesion which, in particular, should be subjected to cytological examination.

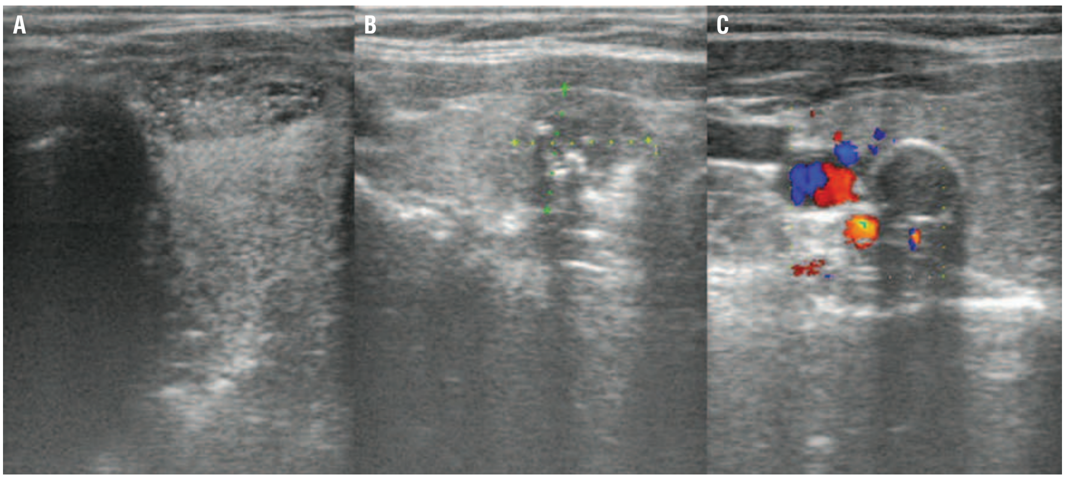

Figure 11. *Three main types of calcifications in thyroid lesions:* ***A.*** *Microcalcifications;* ***B.*** *Macrocalcifications;* ***C.*** *„Egg-shell" or rim calcification*

Rycina 11. *Trzy podstawowe rodzaje zwapnień w obrębie zmian ogniskowych tarczycy:* ***A.*** *Mikrozwapnienia;* ***B.*** *Makrozwapnienia;* ***C.*** *Zwapnienia typu „skorupki jajka" lub obrączkowate*

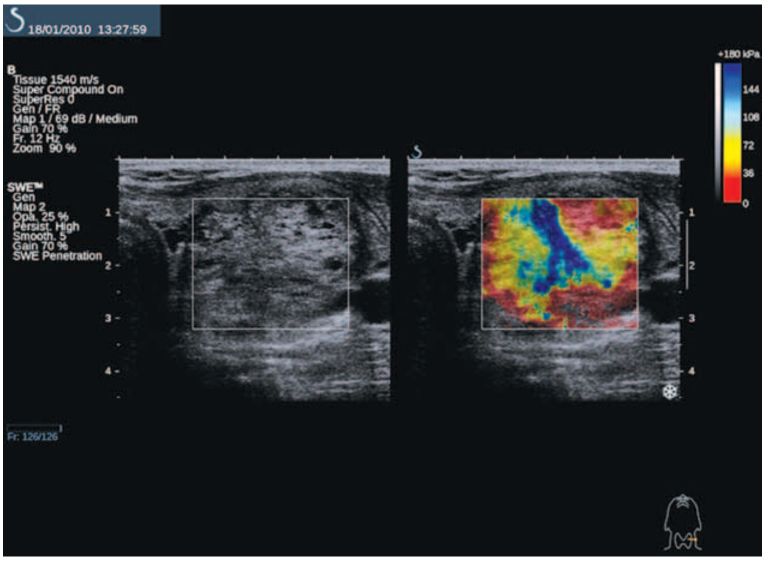

Figure 12. *The evaluation of elasticity of a thyroid nodule by sonoelastography. Blue colour indicates regions of high level of stiffness, while red indicates those of high elasticity*

Rycina 12. *Ocena elastyczności guzka tarczycy w badaniu sonoelastograficznym. Niebieski kolor wskazuje obszary o dużej sztywności, kolor czerwony wskazuje obszary o dużej elastyczności*

Although ultrasound examination is not one which distinguishes malignant thyroid lesions from benign ones, there are some features of thyroid nodules which require particular vigilance. Nonetheless, the characteristics mentioned below are only suggestive of a malignant process, but do not determine the diagnosis. However, it is important to highlight the sonographic features of malignancy in the description of thyroid lesions, if present. Table I summarizes the ultrasound features suggesting thyroid malignancy [9, 10]. Figure 13 presents examples of "sonographically suspected" lesions, which proved to be thyroid cancers. It has to be remembered that features such as size or location of the nodule are not predictive of its benign or malignant character [9]. On the other hand, lesions which are not sono-

Table I. ***Ultrasound features of "sonographically suspected" thyroid nodules***

Tabela I. ***Ultrasonograficzne cechy ognisk tarczycy „podejrzanych sonograficznie"***

Solitary
Solid
Hypoechogenic
Diffused margins
Irregular shape
Micro- and macrocalcifications
Taller than wide
Increased central vascularisation
Hard
Surrounding enlarged suspected lymph nodes

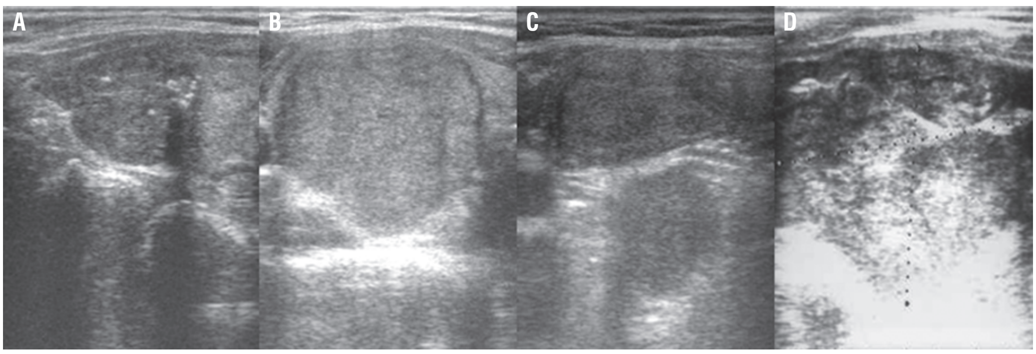

Figure 13. *Examples of "sonographically suspected" nodules which turned out to be thyroid cancers.* ***A.*** *Papillary cancer.* ***B.*** *Follicular cancer.* ***C.*** *Medullary cancer.* ***D.*** *Anaplastic cancer*

Rycina 13. *Przykłady „podejrzanych sonograficznie" ognisk w tarczycy, w przypadku których zdiagnozowano raka tarczycy.* ***A.*** *Rak brodawkowaty.* ***B.*** *Rak pęcherzykowy.* ***C.*** *Rak rdzeniasty.* ***D.*** *Rak anaplastyczny*

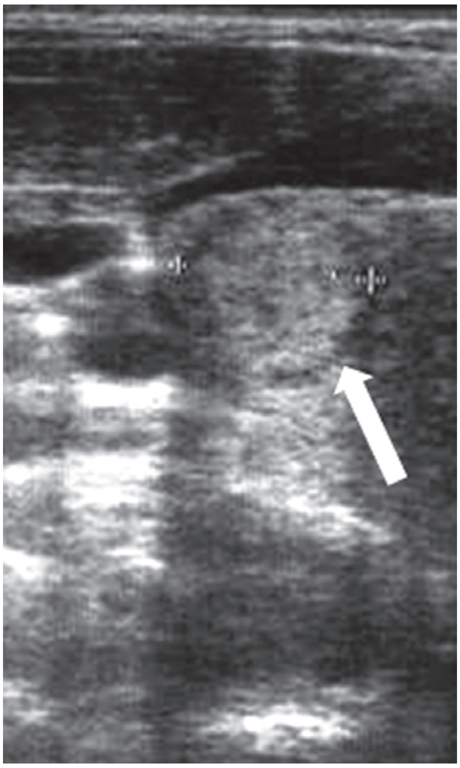

Figure 14. *An isoechogenic thyroid nodule, with regular borders and no microcalcifications, which appeared to be thyroid cancer*

Rycina 14. *Ognisko izoechogeniczne o regularnych granicach bez mikrozwapnień zdiagnozowane jako rak brodawkowaty tarczycy*

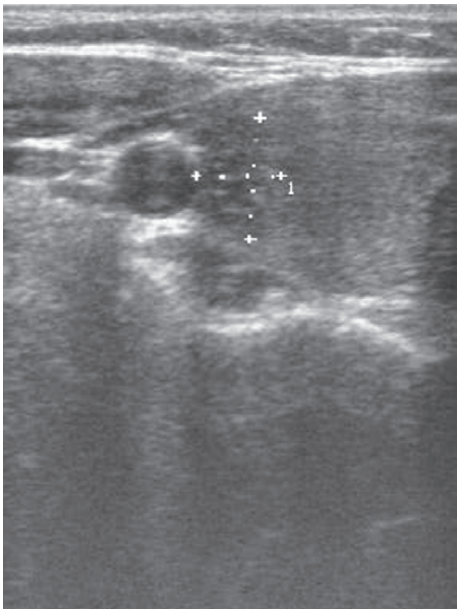

Figure 15. *Papillary microcarcinoma (9 × 6 mm) in a patient with multinodular goiter. The remaining larger nodules were benign. In multinodular goiter, not only the largest nodules should be described and diagnosed cytologically, but especially those with features suggestive of malignant character*

Rycina 15. *Mikrorak brodawkowaty tarczycy (9 × 6 mm) u pacjentki z wolem wieloguzkowym. Pozostałe większe zmiany ogniskowe były łagodne. W przypadku wola wieloguzkowego należy opisywać i diagnozować cytologiczne nie tylko największe ogniska, ale przede wszystkim te, które posiadają cechy sugerujące ich złośliwy charakter*

graphically suspected (isoechogenic, of regular shape, with no microcalcifications) may appear to be thyroid cancers (Fig. 14). Therefore, the confirmation of the diagnosis of a malignant thyroid lesion can only be obtained preoperatively by a cytological examination of aspirates from an ultrasound-guided fine-needle aspiration biopsy, or by a histopathological examination, postoperatively.

In the case of multinodular goiter, to simplify the report from the examination, it is advised to use the term "multifocal changes" and provide a detailed description of only the largest or clinically important nodules, most suspected of malignant character (Fig. 15).

One frequently made mistake in thyroid ultrasound examination reports is using terms reserved for pathologists in the description of sonographically diagnosed thyroid lesions. "Nodule" (although the term is used interchangeably in the paper with "lesion" to avoid repetitions) is a term used rather for palpable abnormalities, while in the thyroid ultrasound examination report the term "focal lesion" should rather be used for clarity. Bearing in mind the fact that thyroid ultrasound is a typical morphological examination, and on its basis it is not possible to distinguish malignant lesions from benign ones, the term "adenoma", frequently used to describe mixed solid/cystic nodules of regular shape, ought to be omitted. Adenoma is a strictly pathological expression, and contains the strong suggestion of benign character of the lesion, which might influence the future management of this patient.

Finally, the sequence in which all the elements of the examination are performed and then reported is not particularly important. However, it is crucial to adhere to an approach and an order for each examination once adopted to minimize the risk of omitting important elements of a thyroid evaluation.

Diagnostic challenges in ultrasound diagnostics of different thyroid pathologies

Thyroid developmental anomalies

The thyroid is an organ particularly prone to morphogenetic variability. Therefore, sonographers can come across different types of thyroid developmental abnormalities, which can be the cause of many diagnostic pitfalls.

Thyroid agenesis is a consequence of the disturbed development of thyroid primordium, or its involution at the very beginning of embryogenesis. This results in a complete lack of functional thyroid tissue, which is also called athyreosis. On ultrasound examination of the neck, the thyroid cannot be visualized in its normal

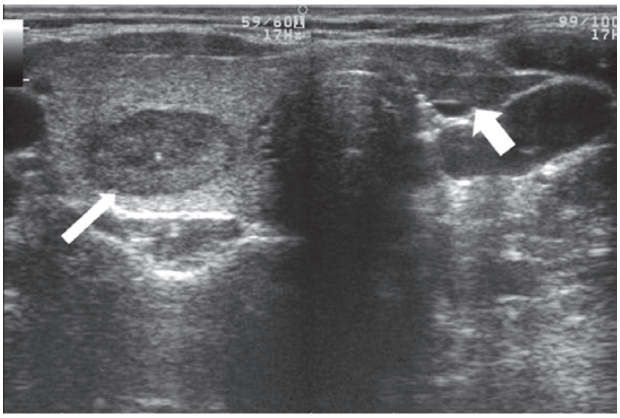

Figure 16. *Thyroid hemiagenesis. Note the indentation of neck muscles on the left side (thick arrow), compensatory enlargement and hypoechogenic nodule of the right thyroid lobe (thin arrow)*

Rycina 16. *Hemiagenezja tarczycy. Widoczne wpuklanie się mięśni szyi po stronie lewej (grubsza strzałka) oraz kompensacyjny przerost prawego płata tarczycy, zawierającego hypoechogeniczne ognisko (cieńsza strzałka)*

location or in any of the possible ectopic locations. Only connective tissue or sometimes small cystic structures of unknown origin and significance can be found within the thyroid bed. When the thyroid lobes are not developed, indentation of the sternohyoid and sternothyroid muscles into the thyroid bed can be observed. In some patients these can be mistaken for hypoechogenic thyroid tissue and erroneously interpreted as a thyroid lobe. The same phenomenon, but unilateral, is observed in the case of thyroid hemiagenesis (Fig. 16). Moreover, a single thyroid lobe often presents compensative enlargement, every so often accompanied by a nodular change. Quite frequently, heterogeneous decreased echogenicity may be present [15]. It is also possible that no thyroid tissue can be found in its typical location. In such a case, it is important to look for an ectopic thyroid gland, which most often can be found in the lingual or sublingual position (Fig. 17). To do this, the ultrasound probe should be placed in the upper part of the neck, in the medial line just below the jaw, and the examiner should look for tissue of echogenicity resembling the thyroid near the tongue. The tongue can be easily identified among the surrounding anatomical structures by asking the patient to move it. A sublingual thyroid is defined as the presence of ectopic thyroid tissue between the geniohyoid and mylohyoid muscles. Sporadically, an ectopic thyroid may be found in the supra- and infrahyoid, or prelaryngeal location. One of the forms of a disturbed thyroid embryogenesis is thyroid hypoplasia, occurring when a thyroid of normal location has a diminished volume, insufficient to provide adequate hormonal secretion. It has to be remembered that, as well as a normally developed thyroid gland, the presence of thyroglossal duct remnants, like a medial cyst of the neck or pyramidal lobe, is possible. The former develops when the thyroglossal duct instead of involuting remains unchanged, and its lumen fills with fluid. In the wall of the cyst, the foci of thyroid tissue can be found, which can also undergo neoplastic transformation (Fig. 18). Most often the cyst displays a infrahyoid location, but it can also be found in the suprahyoid, intralingual, intralaryngeal, or even retrosternal location. On the ultrasound examination, the thyroglossal duct cyst presents as

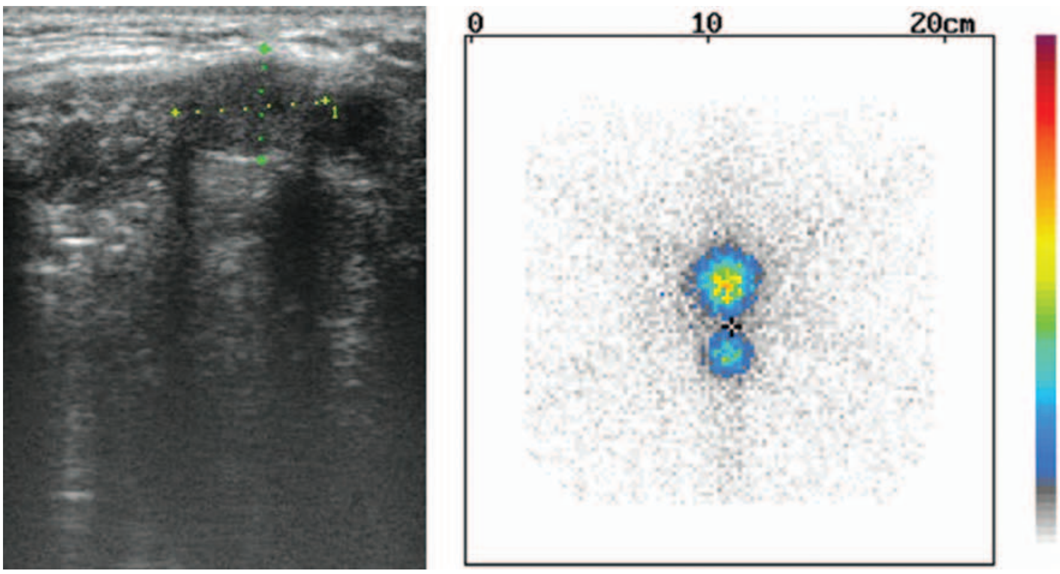

Figure 17. *Ectopic lingual thyroid in a patient with congenital hypothyroidism.* ***A.*** *Ultrasound picture.* ***B.*** *confirmation by scintiscan*

Rycina 17. *Ektopowa tarczyca językowa u pacjenta z wrodzoną niedoczynnością tarczycy.* ***A.*** *Obraz ultrasonograficzny.* ***B.*** *Potwierdzenie w badaniu scyntygraficznym*

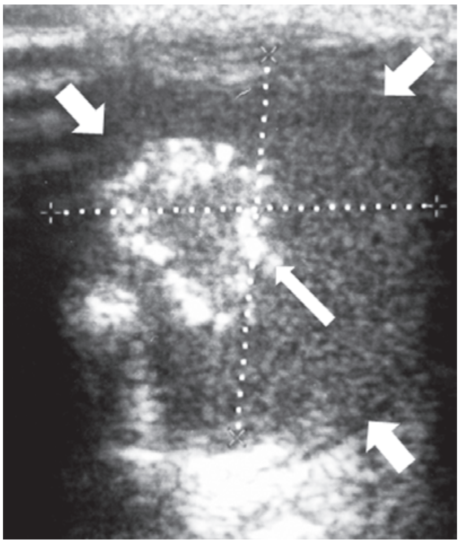

Figure 18. *Thyroid papillary cancer (thin arrow) in the wall of a thyroglossal duct cyst (thick arrows)*

Rycina 18. *Rak brodawkowaty tarczycy (cieńsza strzałka) w ścianie torbieli przewodu tarczowo-językowego (grubsza strzałka)*

an anechogenic structure with fluid inside and posterior enhancement typical for cystic lesions. In the case of inflammation, the fluid changes from clear and serous to denser with some echoes inside. Sometimes only a very small cyst can be noticed as a small hypoechogenic lesion at the level of the isthmus. The pyramidal lobe is a remaining caudal part of the thyroglossal duct, which, due to its commonness, is regarded as an element of a properly developed thyroid [16]. It presents as additional thyroid tissue which varies in size and is often longer in women. It is attached to the thyroid in the left part of the isthmus, rarely its medial or right portion; sporadically it can be found in the left lobe [17]. Sometimes, as well as a normal thyroid, an accessory thyroid gland can be found. On a sonographic examination, the accessory tissue of thyroid echogenicity can be located anywhere along its embryological path of descent.

Simple goiter

Simple goiter on thyroid ultrasound is characterised by diffuse enlargement of the thyroid and homogeneous normal echogenicity. In some cases, echogenicity might be increased and slightly heterogeneous, even some small cystic elements or calcifications may be present. Under L-thyroxine and/or iodine supplementation, a reduction in size of the thyroid is usually observed.

Diffuse autonomy of the thyroid

One of the sonographic diagnostic problems is diffuse thyroid autonomy. There is no typical ultrasound picture of this pathology. The aetiopathological background for this hyperthyroid state is the autonomous function of thyroid follicles, diffusely spread in the whole thyroid parenchyma, which do not form any visible nodules and are not connected with an increase in the anti-TSH receptor autoantibodies concentration. The thyroid may be completely normal or slightly hypoechogenic, due to the accelerated emptying of thyroid follicles from thyroglobulin. The coexistence of simple or nodular thyroid goiter is possible.

Thyroid nodular disease

The prevalence of thyroid focal lesions detected on an ultrasound examination according to different studies reaches as much as 19–67% [18, 19]. Increasing detectability of thyroid nodules makes the management of these patients a constantly growing problem. The role of thyroid ultrasound examination is not only diagnosis, in which ultrasound guided fine-needle aspiration biopsy is a gold standard, but also in monitoring for disease progression, as well as the effectiveness of both pharmacological and surgical treatment. In the case of the former, the follow-up includes monitoring for any change in the size or character of the nodules and the emergence of novel ones. Enlarging nodules, especially under L-thyroxine treatment, require the consideration of surgical treatment. Patient follow-up after thyroidectomy, performed due to benign thyroid nodular changes, requires evaluation for the recurrence of nodular disease. After thyroidectomy, the ultrasound assessment of the thyroidal bed is quite a difficult task due to the development of adhesions and cicatrisation, and the fact that normal anatomical relationships are disturbed after surgery. Thyroidal residues often have a decreased heterogeneous echogenicity. In the thyroid bed, the remnants of the thyroid capsule or connective tissue might also be visualized. If a malignant lesion was detected on the histopathological examination, postsurgical ultrasound evaluation is additionally needed, not only to monitor the thyroid bed for any signs of recurrence, but also to assess the cervical lymph nodes (Fig. 19). If the thyroid remnants volume exceeds 2.0-2.5 ml, the decision to perform restrumectomy should be seriously considered.

Autoimmune thyroid disease

Hypoechogenic thyroid is encountered in all thyroid autoimmune processes, of which the most common is Hashimoto's thyroiditis. The background for thyroid decreased echogenicity in thyroiditis is the destruction of the thyroid by autoantibodies and lymphocytic infiltration. Graves' disease, on the other hand, is connected with an enhanced emptying of thyroid follicles and their decreased size, due to the overstimulation with anti-TSH receptor autoantibodies and hypervascularization.

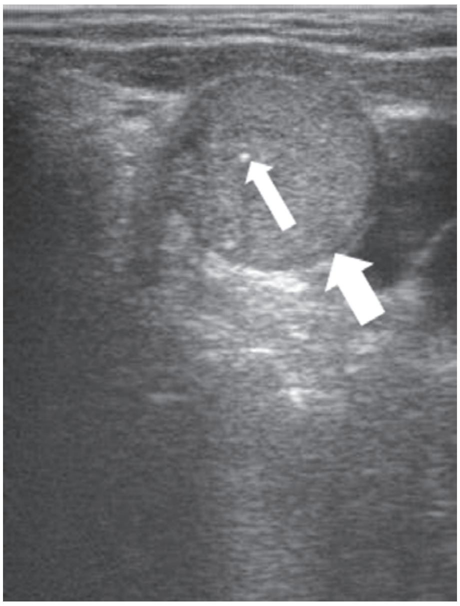

Figure 19. *Recurrence of thyroid papillary cancer. Hypoechogenic lesion (thick arrow) with microcalcifications (thin arrow)*

Rycina 19. *Nawrót raka brodawkowatego tarczycy. Hipoechogeniczna zmiana (grubsza strzałka) z mikrozwapnieniami (cieńsza strzałka)*

Graves' disease

The main characteristic of the ultrasound picture in Graves' disease is diffused and marked hypoechogenicity. Echogenicity is also heterogeneous, with the picture often compared to Swiss cheese because of multiple, small, deeply hypoechogenic areas in the initial phase of the disease. In contrast to thyroiditis, where echogenicity is focally changed, in Graves' disease the whole thyroid is deeply hypoechogenic. The thyroid is especially enlarged in the antero-posterior dimension, which causes a kind of spherical shape of the gland. The application of the Doppler technique allows the visualization of a highly increased vascularization of the thyroid (Fig. 6A). In contrast to Hashimoto's thyroiditis, the return of a normal thyroid appearance is possible in the time of remission. In patients with long lasting Graves' disease, especially in those with a history of radioiodine treatment, linear hyperechogenic fibres can be seen, constituting a marker of fibrosis. It should also be remembered that about 15% of cases of Graves' disease present a normal thyroid ultrasound picture; thus, normal thyroid echogenicity does not exclude its diagnosis. Graves' disease may also overlap with a previously changed thyroid parenchyma. Moreover, thyroid nodules, which are often hyperechogenic in comparison to the surrounding deeply hypoechogenic thyroid parenchyma, may co-occur. A very rare condition is the coexistence of autonomous thyroid nodule with Graves' disease, which is called Marine-Lenhart's syndrome.

Autoimmune thyroiditis

Hashimoto's thyroiditis

Decreased heterogeneous echogenicity and numerous hypoechogenic areas (pseudo-nodules) are typical for Hashimoto's thyroiditis (Fig. 6B). The echogenicity is very similar to the muscles, so it might be difficult to mark the border between the surrounding anatomical structures and the thyroid gland (Fig. 2B). The picture sometimes resembles that found in Graves' disease. However, there are some important differences. On Doppler imaging, in contrast to Graves' disease, decreased vascularization and low blood flow can be detected. Also, the picture of Swiss cheese is not very common and can be observed only in the early phase of the disease. The initial stage of chronic thyroiditis is characterized by the presence of enlarged and elongated lymph nodes, located mainly under the sternocleidomastoid muscle, in the pretracheal region, or below the lower poles of the thyroid. Thyroid volume varies depending on the phase of the disease. At first, the thyroid might be of normal size or even enlarged; however, it rarely becomes spherical in shape, but is rather enlarged in its transverse dimension. In the late phase of Hashimoto's thyroiditis, thyroid atrophy is common. Additionally, the late phase is often accompanied by fibrosis and replacement of functional thyroid tissue by connective tissue, which appears as linear white fibres penetrating the gland, or even in some cases dividing it into pseudo-lobular structures. The abnormal thyroid ultrasound picture in Hashimoto's thyroiditis never improves and remains changed for the rest of the patient's life. However, the described ultrasound picture does not have 100% sensitivity; therefore, about 10% of cases of Hashimoto's thyroiditis may present with a completely normal ultrasound appearance.

Silent thyroiditis

The ultrasound picture is not specific enough to allow establishing the diagnosis solely on its basis. This pathology may also be connected with a normal thyroid size end echogenicity. Hypoechogenic areas can be observed, while in extreme cases the condition may resemble subacute thyroiditis. More often than in other types of thyroiditis, in silent thyroiditis the most hypoechogenic area is the anterior part of the thyroid. One of the subtypes of silent thyroiditis is postpartum thyroiditis.

Riedel's thyroiditis

Riedel's thyroiditis is a specific rare subtype of chronic thyroiditis, also known as invasive fibrosis syndrome. The thyroid parenchyma becomes as thick as wood. With time, the thyroid is gradually replaced with connective tissue. On an ultrasound picture, Riedel's thyroiditis presents as a hypoechogenic region with ill-defined margins and marked fibrosis. Due to the fact that the thyroid gland is extremely hard, it may also compress and displace the trachea or even deform its shape [20, 21].

Other types of thyroiditis

Acute thyroiditis

The ultrasound picture of the initial phase of this type of inflammation differs significantly from that in the late phase. Initially, acute thyroiditis can easily be mistaken for subacute thyroiditis because what is observed is the same picture of ill-defined regions of heterogeneous and decreased echogenicity, different in size and shape, which transpose smoothly into those of normal echogenicity. However, within a few days, gradual resolution can be observed with the formation of abscesses presenting as cystic or mixed lesions. Additionally, aspiration of fluid reveals pus.

de Quervain's thyroiditis

On ultrasound examination, subacute thyroiditis presents with an enlargement of the gland, especially in depth. The ill-defined regions of thyroid parenchyma of heterogeneous, and often decreased echogenicity, change smoothly into those of normal echogenicity of different size and shape (Fig. 20). Subacute thyroiditis may overlap previously existing thyroid pathologies, e.g. thyroid nodular disease, even if the patient was previously unaware of it. Most commonly, one lobe is involved; however, this is not the rule, and similar changes may appear in the contralateral lobe, or may even coexist within both lobes. What is typical of this pathology is that due to the applied anti-inflammatory treatment, along with clinical improvement, a substantial evolution of the ultrasound picture and a gradual disappearing of pathological inflammed regions can be observed and no persisting changes remain.

Post-radiative inflammation in patients after radioiodine treatment

Radioiodine treatment induces a state of post-radiative inflammation in the thyroid, which is characterised by hypoechogenicity and heterogeneity of the thyroid parenchyma. Typically, white, hyperechogenic bands appear which indicate the process of fibrosis and are a consequence of functional thyroid parenchyma being replaced by connective tissue. A reduction in the size of the nodules, as well as a decrease in thyroid volume can usually be observed. In some cases, regional cystic degeneration and calcifications may appear.

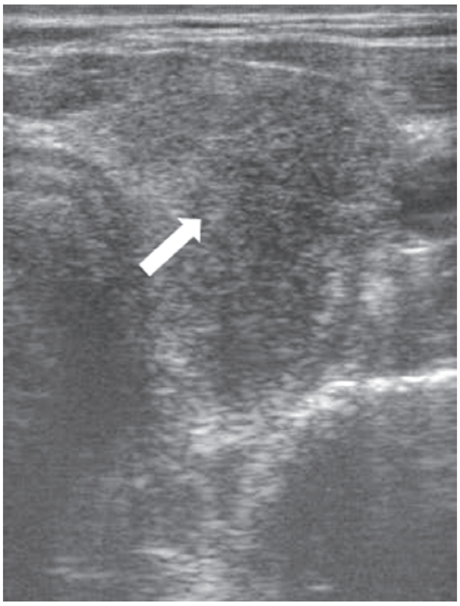

Figure 20. *Sonograhic picture of subacute thyroiditis*
Rycina 20. *Sonograficzny obraz podostrego zapalenia tarczycy*

Secondary thyroid lesions

Some of the focal lesions found in the thyroid do not derive from thyroid tissue and can be metastatic or of lymphatic origin. They usually present similarly to primary thyroid cancers, and are hypoechogenic with diffused margins. Thyroid lymphoma more often develops in patients with Hashimoto's thyroiditis and is usually non-Hodgkin B-cell lymphoma (Fig. 21). Hodgkin's lymphoma of the thyroid can rarely be diagnosed.

Sonographic evaluation of parathyroid glands

Ninety-five per cent of the population has four parathyroid glands, located in the poles of the thyroid lobes; however, their number and location may vary widely. Most unchanged parathyroid glands are the size of a lentil seed, with echogenicity similar to that of the thyroid, and cannot be visualized during ultrasound examination. Nevertheless, enlarged parathyroids are usually hypoechogenic with quite smooth margins and may be easily seen, most often in the extracapsular location, usually between the long muscle of the neck and the trachea, on the posteromedial wall of the thyroid (85%). In 10–15% of cases their location is intra- or perithymal, 3% — intrathyroidal and in the remaining — peripharyngeal or even intrathoracic. They are often solid, but in the case of large lesions, cystic degeneration inside is possible. They are predominantly of elongated or oval to round shape and cannot be visualized until

Figure 21. *Primary non-Hodgkin lymphoma of the thyroid*

Rycina 21. *Pierwotny chłoniak nieziarniczy (non-Hodgkin) tarczycy*

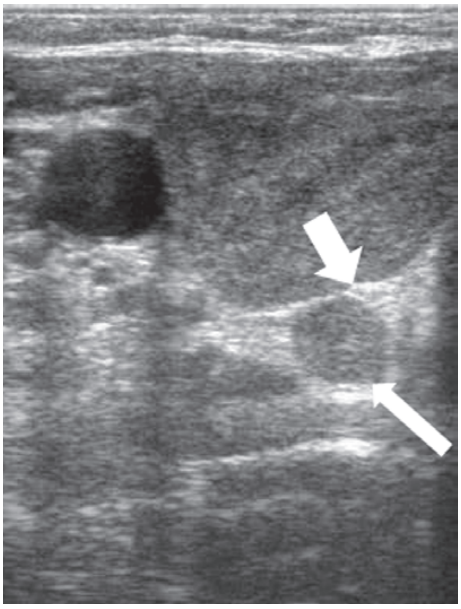

Figure 22. *Parathyroid adenoma. Hypoechogenic lesion located on the posterior wall of the thyroid (thin arrow). Notice the extracapsular location — thick arrow indicates thyroid capsule*

Rycina 22. *Gruczolak przytarczycy. Hipoechogeniczne ognisko zlokalizowane na tylnej ścianie tarczycy (cieńsza strzałka). Należy zwrócić uwagą na pozatorebkową lokalizację zmiany — grubsza strzałka wskazuje torebkę tarczycy*

their size exceeds 5 mm. A solitary enlarged parathyroid gland raises the suspicion of parathyroid adenoma (Fig. 22). Hyperplasia or secondary hyperparathyroidism might be suspected in the event of diffusely enlarged multiple parathyroids. In differential diagnosis, thyroid nodules located close to the dorsal capsule on the posterior wall, lymph nodes, long muscle of the neck, esophagus, or atypically located vessels or nerve trunks should be considered. In the case of a person referred for an ultrasound examination with clinical and laboratory signs of hyperparathyroidism, the whole perithyroidal region of the neck should be accurately screened for the presence of an enlarged parathyroid gland. The result of the examination should primarily describe the size and accurate location of the enlarged parathyroid. In the final diagnosis, a MIBI scintiscan is helpful. However, failure to visualise the gland on a thyroid ultrasound of course does not exclude the diagnosis, due to a possible ectopic location of the parathyroid gland.

Sonographic evaluation of local lymph nodes

Normal lymph nodes are usually solitary, oval, with a visible lymph sinus. On the contrary, suspected lymph nodes are usually round, larger than 10 mm in size, deeply hypoechoic, with diffused margins and a potential to form packages (Fig. 23). The lymph sinus cannot be easily seen. Metastatic lymph nodes also present increased vascularisation on Doppler flow imaging. The concomitant suspected lesion of the thyroid together with abnormal lymph nodes enhances the suspicion of advanced thyroid cancer. The examination of local lymph nodes is a vital part of the assessment of patients with a history of thyroidectomy for thyroid cancer. In such cases, the size and location of every detected lymph node ought to be described together with the indication of any features of the suspected lymph nodes, so that any change in their character and size may be monitored by comparison with previous examinations.

Conclusions

The development of methods applying ultrasound waves has surely not reached a dead end yet, as more and more techniques based on ultrasound technology are still being put into practice. In fact, sonographic evaluation of the thyroid continues to have a great impact on our diagnosis and therapeutic decisions. However, it can never replace the holistic approach, or be interpreted in isolation, without taking the patient's history and clinical data into consideration. Moreover, adequate equipment used for the examination, as well as the experience and training of the sonographer are among the most important determinants of its reliability. Hence, to answer the question in the title of this paper: thyroid USG is not difficult to perform, but constitutes a challenge if it is to be done well.

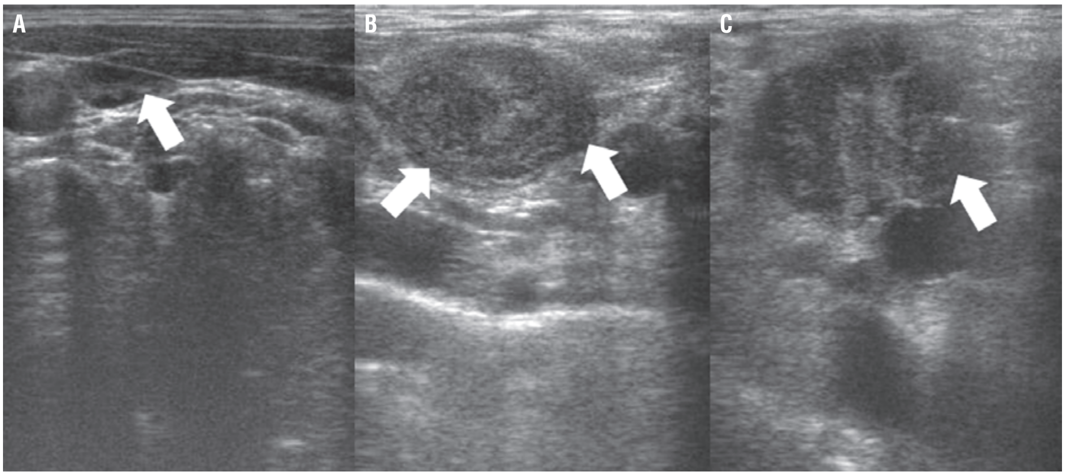

Figure 23. *Lymph nodes.* ***A.*** *Reactive lymph node — oval and with marked sinus.* ***B.*** *Large metastatic cervical lymph node (16 × 12 mm) in a patient with thyroid papillary cancer.* ***C.*** *Polycyclic metastatic lymph nodes forming a package in the supraclavicular area*

Rycina 23. *Węzły chłonne.* ***A.*** *Odczynowy węzeł chłonny — owalny kształt i wyraźna zatoka.* ***B.*** *Duży przerzutowy węzeł szyjny (16 × 12 mm) u pacjenta z rakiem brodawkowatym tarczycy.* ***C.*** *Pakiet policyklicznych przerzutowych węzłów chłonnych w okolicy nadobojczykowej*

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