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Predator-Prey Interactions of the Invasive Jellyfish *Gonionemus Vertens*: Feeding Trials and Ecological Implications

Akhmedov Dilshod Bakhodirovich

Independent Researcher, Bukhara State Medical Institute, Bukhara, Uzbekistan

Abstract According to experts from the World Health Organization (WHO), thyroid gland diseases rank second among endocrine pathologies, after diabetes mellitus. More than 665 million people worldwide suffer from thyroid pathologies, and 1.5 billion people are at risk of developing diseases caused by iodine deficiency. In 2008, on the initiative of the European Thyroid Association, World Thyroid Day was established (Won Sang Yoo and Hyun Kyung, 2016) [1].

Keywords Autoimmune, Thyroid gland, Ultrasound, Humoral, Nodular goiter, Hypothyroidism

1. Introduction

It has now been proven that structural and morphological features and changes play an important role in the development of most thyroid diseases. The progression of autoimmune pathology in the thyroid gland is accompanied by disorders at the humoral and cellular levels of immunity. The manifestation of the cardiorenal continuum, with subsequent damage to the cardiovascular system and kidneys, indicates the presence of an inflammatory process in thyroid hyperfunction (Gryaznova M.A., Khamnueva L.Yu., 2017) [2].

In 1974, the Canadian researcher R. Volpe was the first to substantiate the theory of the autoimmune genesis of diffuse toxic goiter (DTG). According to this theory, a breakdown in the control over the number and function of autoreactive cells is observed in this pathology due to a defect in organ-specific T-suppressor cells.

The prognosis for nodular thyroid formations depends on the stage of tumor development identified during the initial examination. Therefore, the issue of early diagnosis of focal thyroid formations is highly relevant (Campanozzi A. et al., 2019) [3,4].

The evaluation of the echogenicity and echostructure of the thyroid parenchyma is also considered one of the important issues. In thyroid hyperplasia, echogenicity decreases due to increased tissue hydrophilicity, and a medium-to-large granular structure is observed (Barrea L. et al., 2021) [5].

Endocrinological diseases, including thyroid pathologies, are widespread throughout the world, leading to complications, decreased quality of life, and reduced work capacity in patients. This has evolved into not only a medical but also a socio-economic problem. The ongoing research in this medical field shows that its relevance has not diminished [8,9].

The purpose of the study was to evaluate the role of thyroid ultrasound examination in the early diagnosis of thyroid diseases by analyzing the results of this examination [12].

2. Materials and Methods

A total of 139 adult patients diagnosed with thyroid diseases were included in the study, and all of them underwent an ultrasound examination (UE). Of these, 16 (11.51±2.71%) were men and 123 (88.49±2.71%) were women. Women were found to be 7.69 times more frequent than men. The age distribution of the patients was as follows: 20-29 years - 23.02±3.54% (n=32); 30-39 years - 28.78±3.84% (n=40); 40-49 years - 22.30±3.53% (n=31); 50-59 years - 16.55±3.15% (n=23); 60 years and older - 9.35±2.47% (n=13).

The patients were also categorized based on the duration of their illness. It was found that 40.29±4.16% (n=56) of patients had a disease duration of 1-2 years, 24.46±3.65% (n=34) had a duration of 3-4 years, and 12.95±2.85% (n=18) had a duration of 5 years or more. A concerning 20.86±3.45% (n=29) were newly diagnosed upon first consultation for this condition, and 2 patients (1.44±1.01%) had a congenital thyroid pathology. The leading duration of illness was 1-2 years (40.29±4.16%). The high percentage of new diagnoses (20.86±3.45%) was also interpreted as a worrying trend.

Based on the ultrasound conclusions for thyroid diseases, three pathologies were studied. It was found that nodular goiter was present in 44.61±4.22% (n=62) of cases,

* Corresponding author:
dilshod.dilshod.1996@list.ru (Akhmedov Dilshod Bakhodirovich)
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hypothyroidism in 33.09±3.99% (n=46) of cases, and diffuse toxic goiter (DTG) in 22.30±3.53% (n=31) of cases among the patients who underwent UE.

The final diagnoses of thyroid diseases (nodular goiter, diffuse toxic goiter, hypothyroidism) were based on the 11th edition of the International Classification of Diseases (ICD-11, 2022). This classification is based on clinical, instrumental, and laboratory indicators. Although this classification was recommended for use starting February 18, 2022, the transition period is set from 2022 to 2027. Therefore, the main diagnoses for the patients were made based on the old classification (ICD-10, 2007).

The study was conducted in accordance with the World Medical Association's Declaration of Helsinki regarding the inclusion of human subjects in medical research (Helsinki, 1964, last amendment Fortaleza, Brazil, 2013).

In addition to clinical and laboratory diagnostic methods for thyroid diseases, instrumental methods also play a significant role. In particular, ultrasound examination (UE) is crucial for the diagnosis of these diseases and has great diagnostic value. Today, elastography is an innovative technology in the ultrasound diagnosis of thyroid diseases, allowing for a non-invasive assessment of the density and elasticity of tissues and volumetric formations in the organ. The use of elastography in studying patients with nodular thyroid pathology increases the accuracy and specificity of the ultrasound examination.

Ultrasound examinations (UE) for the patients included in the study were performed using a SonoScape S22 ultrasound scanner manufactured in China. This device is equipped with a special Thyroid ElastoScan function, which allows for a qualitative analysis of the thyroid gland parenchyma and nodular formations, as well as a quantitative evaluation of the elasticity contrast index. Elastography allowed for the identification of the following information in patients: the state of lymph nodes located near the thyroid gland; its morphological structure; its volume; the dimensions of both its lobes; and the structure of the isthmus.

The data collected during the study were statistically processed using both parametric and non-parametric analysis methods from traditional variational statistics with the help of the "Excel" software.

3. Results and Discussion

The study presented the UE anatomy and characteristics of the thyroid gland (TG). It was found that the TG was in its typical location—in the lower part of the neck, anterior to the thyroid cartilage and trachea. In all patients, the gland was found to consist of two parts, the right and left lobes, which are connected by the isthmus. It's easy to identify the TG with UE because the organ is separated from the outside world only by the skin and neck muscles, which are the sternohyoid, sternothyroid, and sternocleidomastoid muscles.

In healthy individuals, the TG has a homogeneous echogenicity, and the parenchyma is hyperechoic, making it appear brighter than the surrounding muscles on the ultrasound. All borders of the TG were clearly distinguishable, and no focal pathological changes were detected in the parenchyma. No pathological or aberrant location of the organ was found when viewed in both transverse and longitudinal projections.

In addition to studying the UE parameters in the overall patient group, the parameters were also analyzed comparatively among different nosological units of thyroid diseases: nodular goiter, DTG, and hypothyroidism. The results for the TG parameters among the nosological units are presented in Table 1.

To determine the presence or absence of differences between the nosological units, the UE parameters for nodular goiter, DTG, and hypothyroidism were analyzed and presented in comparison with the indicators of the general group.

In ultrasound examination, when the width parameters of the thyroid gland were determined, the indicators for both lobes in nodular goiter showed a reliable difference from the parameters of the general group ($P<0.05$), (Figure 1).

If the difference in the right lobe was 1.10 times in favor of nodular goiter (20.22±0.46 mm vs. 18.46±0.36 mm), the trend for the left lobe was similar, with a 1.12-fold difference (19.97±0.27 mm vs. 17.87±0.35 mm, $P<0.05$) (Figure 1).

Table 1. Results of a Comparative Study of Thyroid Ultrasound Examination (UE) Parameters in Patients Diagnosed with Thyroid Diseases

Groups		Ultrasound parameters			
		Width 15-20 мм	Thickness, 10-15 мм	Length, 25-60 мм	Volume, 25см³ гача
General group	ўғ	18,46±0,36	22,61±0,42	42,81±0,81	10,27±0,47
	Ч	17,87±0,35	22,05±0,42	42,86±0,80	9,78±0,45
Nodular goiter	ўғ	20,22±0,46*↑	24,19±0,45*↑	47,00±0,87*↑	12,01±0,50*↑
	Ч	19,97±0,27*↑	24,31±0,36*↑	47,36±0,60*↑	12,13±0,39*↑
DTG	ўғ	21,35±0,18*↑	26,45±0,29*↑	49,35±0,33*↑	14,53±0,32*↑
	Ч	20,65±0,17*↑	25,58±0,27*↑	49,18±0,33*↑	13,52±0,28*↑
Hypothyroidisim	ўғ	14,73±0,49*↓	18,23±0,58*↓	34,23±0,14*↓	5,42±0,65*↓
	Ч	13,98±0,48*↓	17,42±0,56*↓	34,09±0,26*↓	4,89±0,61*↓

Note: * - a reliable difference indicator compared to the parameters of the general group; ↑, ↓ - directions of changes.

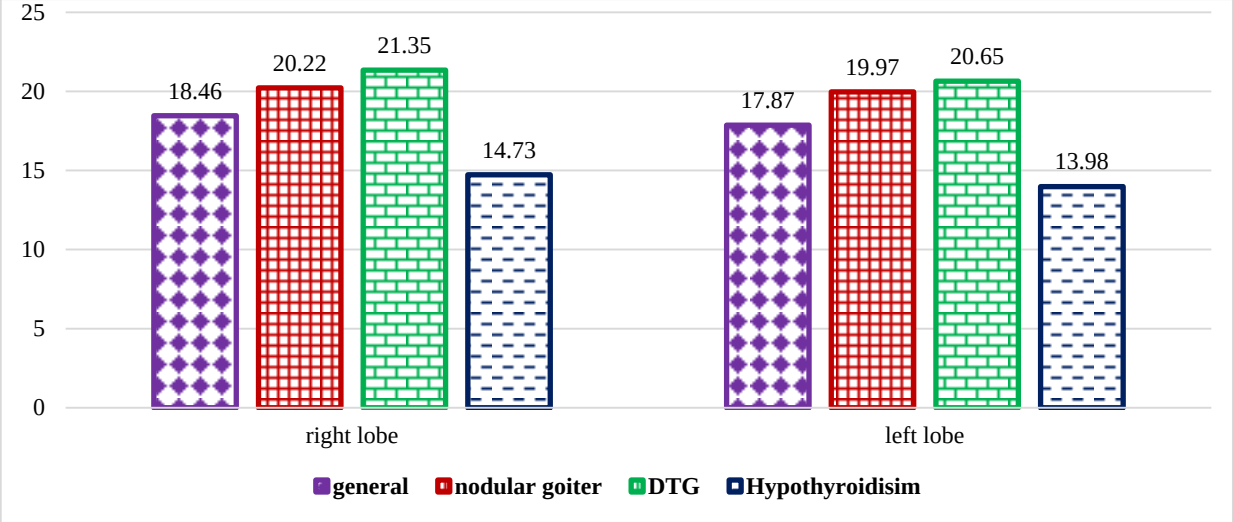

Figure 1. Comparative Indicators of Thyroid Gland Width (in mm) as an Ultrasound Parameter in Patients with Diagnosed Thyroid Diseases

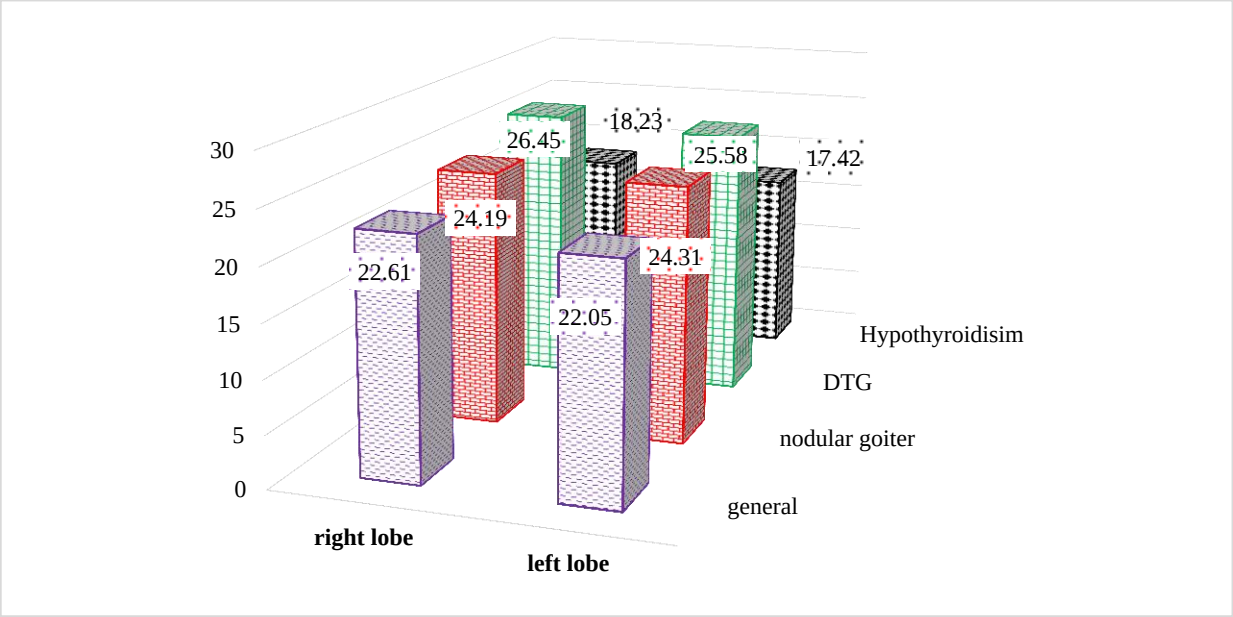

Figure 2. Comparative Indicators of Thyroid Gland Thickness (in mm) as an Ultrasound Parameter in Patients with Diagnosed Thyroid Diseases

The trend and intensity of changes for diffuse toxic goiter (DTG) were also similar to the above, with differences of 1.16 times in the right lobe and 1.16 times in the left lobe (21.35±0.18 mm vs. 18.46±0.36 mm and 20.65±0.17 mm vs. 17.87±0.35 mm, respectively, $P<0.05$). Unlike these two nosological units, the results for hypothyroidism were the reverse.

In hypothyroidism, the thyroid glands ultrasound parameter of width was found to be reduced compared to the general group. The right lobe's width was reliably reduced by up to 1.25 times compared to the general group ($P<0.05$), while the left lobe's width was statistically significantly lower by up to 1.28 times ($P<0.05$). It is noteworthy that the thyroid glands width parameter in patients diagnosed with hypothyroidism was lower not only than the general group but also than those with nodular goiter and DTG. This indicates the high diagnostic value of the thyroid gland width as an ultrasound parameter.

Along with thyroid gland width, its thickness is also considered an important ultrasound sign and is recommended to be determined according to accepted standards. The trend and intensity of differences in thyroid thickness across the nosologies were similar to the previous parameter (thyroid width).

In nodular goiter, the thickness of the right lobe was increased compared to the general group (by 1.07 times, $P<0.05$), and a similar difference was found in the left lobe (a 1.10-fold difference, $P<0.05$).

A more intensive difference was observed in the thyroid thickness of patients diagnosed with DTG, with differences of 1.17 and 1.16 times for the right and left lobes, respectively ($P<0.05$). In both of these nosological units, the thickness of the organ (from UE results) was reliably increased ($P<0.05$) (Figure 2).

In addition to the thyroid glands width, its thickness was also noted to have decreased in cases of hypothyroidism. This indicator was found to be reliably lower not only than the parameters of the general group but also significantly less than the data for other thyroid diseases (DTG, nodular goiter) (P<0.05).

Specifically, the decrease in the right lobe was statistically significant by 1.24, 1.33, and 1.45 times compared to the general group, nodular goiter, and DTG, respectively (P<0.05). The same result was observed for the left lobe, with a reliable decrease of 1.27, 1.40, and 1.47 times, respectively (P<0.05). The fact that the thyroid gland's thickness, like its width, can show a difference between nosologies, indicates its high diagnostic value.

According to the UE standard, the length of the thyroid gland is also determined and provided in specific numbers for every patient suspected of having a thyroid disease. This length, based on the degree of change, helps determine the specific pathology. The trend and intensity of organ changes across the nosologies for gland length were similar to those for its width and thickness.

In nodular goiter and DTG, the UE parameter for organ length was reliably higher than the parameters of the general group (P<0.05). The increase was also found in the thyroid length of patients diagnosed with hypothyroidism (P<0.05). In nodular goiter, the length of the right and left lobes was reliably greater than the general group by 1.10 and 1.11 times, respectively (P<0.05). In DTG, the thyroid length determined by UE was in a similar range, with the right and left lobes being statistically significantly larger than the general group by 1.15 and 1.14 times, respectively (P<0.05) (Figure 3).

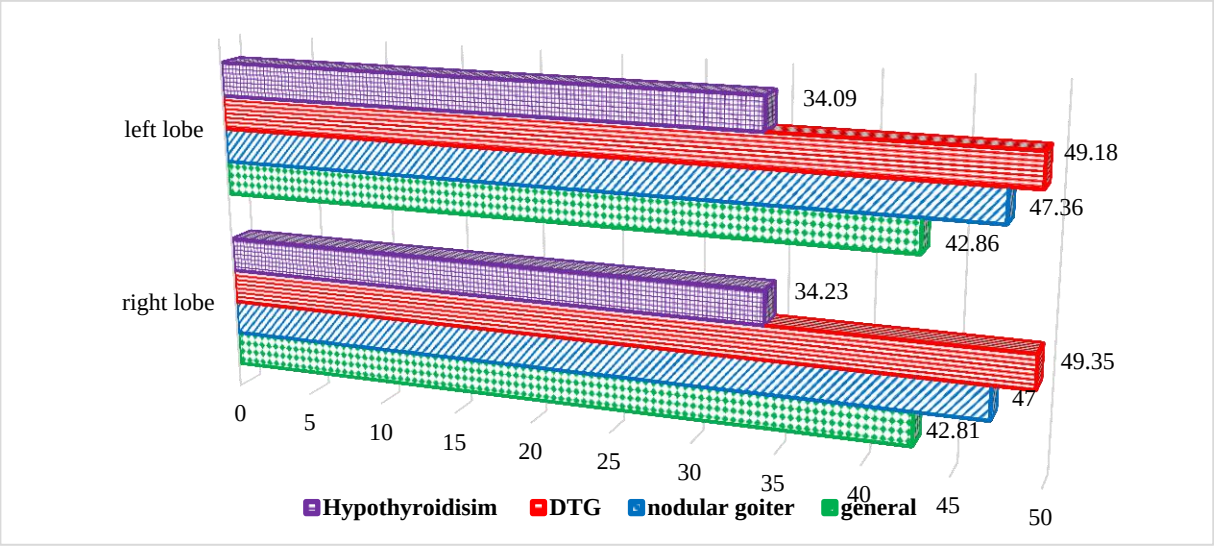

Figure 3. Comparative Indicators of Thyroid Gland Length (in mm) as an Ultrasound Parameter in Patients with Diagnosed Thyroid Diseases

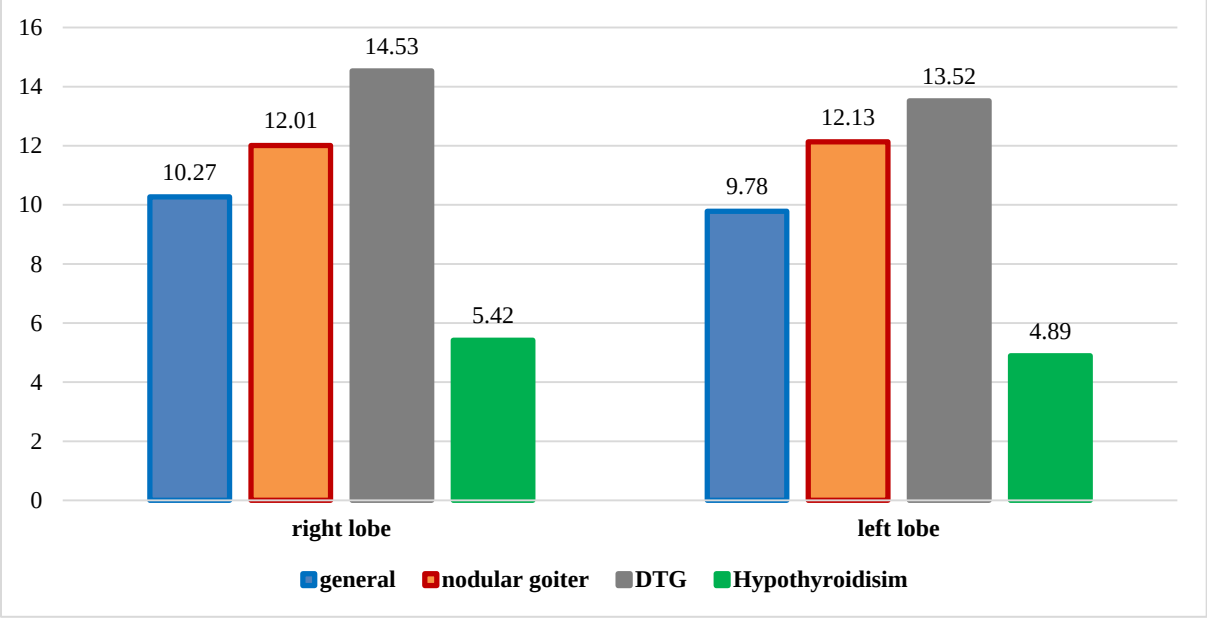

Figure 4. Comparative Indicators of Thyroid Gland Volume (in cm ^{3}) Determined by Ultrasound in Patients with Thyroid Diseases

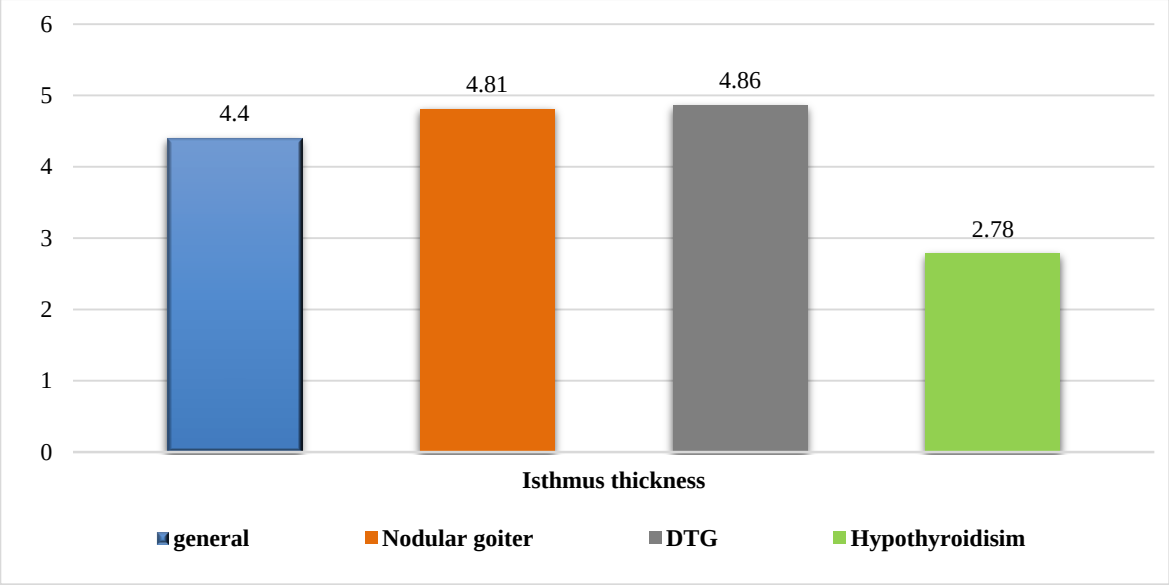

Figure 5. Measurements of the Thyroid Gland Isthmus (in mm) Determined by Ultrasound in Patients with Thyroid Diseases

During the ultrasound examination for hypothyroidism, the length of the thyroid gland was measured, and the resulting figures were compared with the parameters of the combined general group of thyroid diseases, nodular goiter, and DTG. The results showed that this parameter was reliably lower than the indicators of the compared groups and nosologies ($P<0.05$).

This difference was 1.25 times for the right lobe and 1.26 times for the left lobe compared to the general group. The decrease in the thyroid gland's length as an ultrasound parameter was shown to be related to the pathogenetic features of hypothyroidism. A decrease in thyroid gland length was also observed compared to nodular goiter and DTG ($P<0.05$).

The results showed that the degree and ratio of changes in the thyroid gland's volume, as determined by UE, were similar to previous indicators. The thyroid gland's volume was reliably higher in nodular goiter and DTG compared to the general group, while the opposite was true for hypothyroidism. Looking at the numbers, in nodular goiter, the thyroid gland's volume was 12.01 ± 0.50 cm ^{3}in the right lobe and 12.13 ± 0.30 cm ^{3}in the left lobe, with both indicators being reliably greater than the general group parameters by 1.17 and 1.24 times, respectively ($P<0.05$).

The trend of changes was the same in DTG, but the intensity was higher, with the volume of the right and left lobes being 14.53 ± 0.32 cm ^{3} and 13.52 ± 0.28 cm ^{3}, respectively. This showed a reliable increase of 1.41 and 1.38 times, respectively, compared to the general group ($P<0.05$). Thus, in both nosological units of thyroid disease, the organ's volume from the ultrasound results was reliably higher than the general group indicators ($P<0.05$), while remaining within the accepted reference ranges for these parameters (Figure 4).

Ultrasound examination of the thyroid gland in patients diagnosed with hypothyroidism revealed the following changes in volume: the average volume of the right lobe was 5.42 ± 0.65 cm ^{3} and the left lobe was 4.89 ± 0.61 cm ^{3}. These figures were reliably smaller compared to the same parameters in the general group, nodular goiter, and DTG. Specifically, the right lobe of the thyroid gland was smaller by 1.89, 2.22, and 2.68 times, respectively ($P<0.001$), while the left lobe was smaller by up to 2.0, 2.48, and 2.76 times, respectively ($P<0.001$).

The variability of the thyroid gland's volume is clearly related to the pathogenetic state of these nosological units, the degree of impact on the organ, and the stage of pathological development. One of the key diagnostic signs in ultrasound is the thickness of the organ's isthmus (with a reference range of 4-8 mm). The results of this parameter are presented in a comparative manner in Figure 5.

While this indicator was 4.04 ± 0.16 mm in the general group, this parameter increased to 4.81 ± 0.6 mm in nodular goiter (a 1.19-fold increase compared to the general group, $P<0.05$). In DTG, it increased to 4.86 ± 0.14 mm (a 1.20-fold increase, $P<0.05$). However, in hypothyroidism, this parameter reliably decreased by 1.45 times compared to the general group ($P<0.05$), measuring 2.78 ± 0.26 mm. Therefore, the trend and intensity of changes in the thyroid glands width, thickness, length, and volume across the groups and nosological units were maintained, and the ratio of differences in the isthmus thickness of this organ was significant. This indicates the high diagnostic value of the ultrasound parameter, and it is described as an important indicator for interpreting ultrasound anatomy.

As noted above, the average TI-RADS score in the overall group was 1.73 ± 0.05 units, with no malignant tumors found and no need for a biopsy. The indicators of this parameter across the nosological units are also presented (Table 2).

Table 2. Indicators for Determining the TI-RADS Parameter via Ultrasound in Patients with Thyroid Diseases

Groups	T1-RADS
General group, n=139	1,73±0,05
Nodular goiter, n=62	2,06±0,06
DTG, n=31	2,03±0,06
Hypothyroidisim, n=46	1,18±0,07

The results obtained showed a difference among the nosological units, but these figures remained within the reference ranges. The TI-RADS method also confirmed the absence of malignant tumors in all patients.

4. Conclusions

1. The trend and intensity of changes in the width, thickness, length, and volume of the thyroid gland remained consistent across the nosological units (nodular goiter, DTG, hypothyroidism). The ratio of differences in the thickness of the organ's isthmus was particularly significant. This highlights that these ultrasound parameters are important indicators for interpreting the organ's ultrasound anatomy. When diagnosing thyroid pathologies with ultrasound, special attention should be paid to determining and evaluating the thickness of the gland, without neglecting the diagnostic value of its width, length, and volume.
2. Two computer programs were developed to assess the degree of structural changes occurring in the organ and the level of utilization of elastographic indicators. These programs use the elastographic parameters of the thyroid gland to create a basis for the early diagnosis and prognosis of the outcome of its diseases.

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