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CLINICAL EFFECTIVENESS OF MODERN ULTRASOUND DIAGNOSTICS AND THE TI-RADS SYSTEM IN ASSESSING THE RISK OF MALIGNANCY IN THYROID NODULES

Abstract

This article examines the clinical effectiveness of modern ultrasound diagnostics and the TI-RADS (Thyroid Imaging Reporting and Data System) classification in assessing malignancy risk in thyroid nodules. Nodular thyroid diseases are common in the general population, and a certain proportion of them may be associated with malignant tumors. Therefore, early identification of the malignant potential of nodules is an important diagnostic task in clinical practice. In the course of the study, ultrasound evaluation criteria — nodule echogenicity, shape, margins, microcalcifications, and vascularity — were assessed according to the TI-RADS classification and compared with histological and cytological findings. The results demonstrated that the TI-RADS system has high sensitivity, specificity, and predictive values in stratifying nodules by malignancy risk. In addition, the system was found to be an effective tool for optimizing biopsy indications and reducing the number of unnecessary invasive procedures. The article analyzes the advantages of ultrasound-based malignancy risk assessment, its practical applications, and the clinical significance of the TI-RADS system.

Keywords: thyroid gland, nodules, TI-RADS, ultrasound diagnostics, malignancy risk, differential diagnosis, microcalcification, cytology, thyroid nodule, risk stratification.

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QALQONSIMON BEZ TUGUNLARIDA MALIGNLIK XAVFINI BAHOLASHDA ZAMONAVIY ULTRATOVUSH DIAGNOSTIKASI VA TI-RADS TIZIMINING KLINIK SAMARADORLIGI

ANNOTATSIYA

Ushbu maqolada qalqonsimon bez tugunlarida malignlik xavfini baholashda zamonaviy ultratovush diagnostikasi va TI-RADS (Thyroid Imaging Reporting and Data System) tasnifining klinik

samaradorligi o'rganildi. Qalqonsimon bez nodulyar kasalliklari aholi orasida keng tarqalgan bo'lib, ularning ma'lum qismi malign o'sma bilan bog'liq bo'lishi mumkin. Shuning uchun tugunlarning malign potentsialini erta aniqlash klinik amaliyotda muhim diagnostik vazifa hisoblanadi. Tadqiqot davomida ultratovush tekshiruvi mezonlari — tugunning echogenligi, shakli, konturlari, mikrokalsifikatsiyalar, vaskulyarizatsiya xususiyatlari — TI-RADS klassifikatsiyasi bo'yicha baholandi va gistologik hamda sitologik natijalar bilan taqqoslandi. Natijalar TI-RADS tizimining tugunlarni malignlikka ko'ra guruhlashda sezgirlik, spetsifiklik va prediktiv qiymatlari yuqori ekanligini ko'rsatdi. Shuningdek, tizim biopsiya uchun ko'rsatmalarni optimallashtirishda va ortiqcha invaziv protseduralar sonini kamaytirishda samarali vosita bo'lishi aniqlangan. Maqola ultratovush asosida malignlik xavfini baholashning afzalliklari, amaliy qo'llanish imkoniyatlari va TI-RADS tizimining klinik ahamiyatini tahlil qiladi.

Kalit so'zlar: qalqonsimon bez, tugunlar, TI-RADS, ultratovush diagnostikasi, malignlik xavfi, differensial diagnostika, mikrokalsifikatsiya, sitologiya, thyroid nodule, risk stratifikatsiya.

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КЛИНИЧЕСКАЯ ЭФФЕКТИВНОСТЬ СОВРЕМЕННОЙ УЛЬТРАЗВУКОВОЙ ДИАГНОСТИКИ И СИСТЕМЫ TI-RADS В ОЦЕНКЕ РИСКА ЗЛОКАЧЕСТВЕННОСТИ УЗЛОВ ЩИТОВИДНОЙ ЖЕЛЕЗЫ

АННОТАЦИЯ

В данной статье изучена клиническая эффективность современных ультразвуковых методов диагностики и классификации TI-RADS (Thyroid Imaging Reporting and Data System) в оценке риска малигнизации узлов щитовидной железы. Узловые заболевания щитовидной железы широко распространены среди населения, и определённая их часть может быть связана со злокачественными новообразованиями. Поэтому раннее выявление малигненного потенциала узлов является важной диагностической задачей в клинической практике. В ходе исследования критерии ультразвукового обследования — эхогенность узла, его форма, контуры, микрокальцификаты, особенности васкуляризации — оценивались согласно классификации TI-RADS и сравнивались с гистологическими и цитологическими данными. Полученные результаты показали, что система TI-RADS обладает высокой чувствительностью, специфичностью и предиктивными значениями при стратификации узлов по риску малигнизации. Кроме того, было установлено, что данная система является эффективным инструментом для оптимизации показаний к биопсии и снижения числа избыточных инвазивных процедур. В статье анализируются преимущества ультразвуковой оценки риска

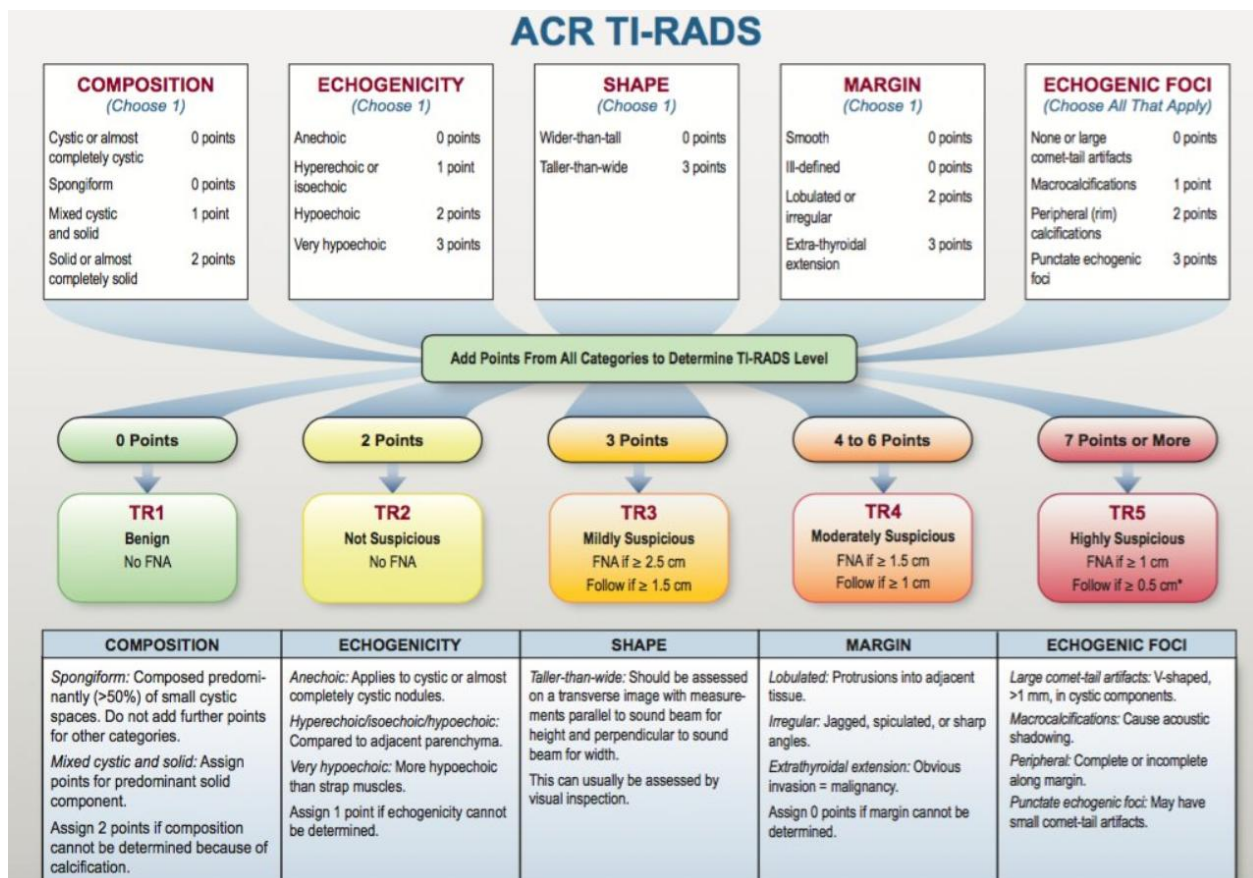
малигнизации, возможности практического применения и клиническая значимость системы TI-RADS.

Ключевые слова: щитовидная железа, узлы, TI-RADS, ультразвуковая диагностика, риск малигнизации, дифференциальная диагностика, микрокальцификация, цитология, thyroid nodule, риск-стратификация.

INTRODUCTION

Thyroid nodules (TNs) are among the most common endocrine pathologies encountered in clinical practice, with a prevalence reaching 20–70% in the general population. Although advancements in radiological and ultrasound (US) technologies have increased the detection rate of thyroid nodules, the majority of them are clinically insignificant (benign). At the same time, approximately 5–15% of nodules carry a potential risk of malignant transformation, making their timely and accurate assessment a critically important task. Early detection of thyroid cancer improves treatment effectiveness, enhances patient prognosis, and reduces the number of unnecessary invasive procedures.

In recent years, the TI-RADS (Thyroid Imaging Reporting and Data System) classification has been increasingly used to establish a standardized approach for evaluating thyroid nodules. This system is based on ultrasound features and categorizes nodules according to their level of malignancy risk, helping to determine the necessity of biopsy. TI-RADS is valuable for reducing clinical uncertainty, lowering interobserver variability, and improving the efficiency of healthcare systems by decreasing the number of unnecessary or non-diagnostic biopsies.



Modern ultrasound technologies — high-frequency transducers, Doppler imaging, and elastography — allow for more detailed assessment of nodule structure, stiffness, and vascular characteristics. At the same time, malignancy-associated features (microcalcifications, irregular margins, a “taller-than-wide” shape, hypoechogenicity, etc.) are quantitatively evaluated through the TI-RADS classification. Therefore, improving the ultrasound-based assessment of malignancy risk in thyroid nodules, evaluating the clinical effectiveness of the TI-RADS system, and determining its role in clinical practice are highly relevant issues in contemporary endocrinology and radiology. This study focuses on investigating the diagnostic capabilities of the TI-RADS system, its sensitivity and specificity, and its correlation with histological and cytological findings.

MATERIALS AND METHODS

This study included a total of 126 patients (98 females, 28 males) with thyroid nodules between 2023 and 2025. The participants' ages ranged from 18 to 75 years (mean $\pm$ SD: 47.2 ± 11.6 years).

Ultrasound examination protocol Ultrasound assessment was performed using a high-frequency 7–15 MHz linear transducer. Each nodule was evaluated according to the following criteria:

1. Echogenicity: hypoechoic, iso- or hyperechoic
2. Shape: “taller-than-wide,” “wider-than-tall”
3. Margins: smooth, irregular, infiltrative
4. Calcifications: microcalcifications, macrocalcifications
5. Internal composition: hypoechoic, homogeneous, mixed
6. Vascularity: minimal, perinodular, central

Based on these features, nodules were scored using the ACR TI-RADS system and classified into categories TR1–TR5.

The following table presents the scoring criteria of the ACR TI-RADS system used in the study:

Table 1. TI-RADS scoring criteria for thyroid nodules

Category	Features	Points
Composition	Solid	2
	Mixed	1
Echogenicity	Hypoechoic	2
	Very hypoechoic	3
Shape	Taller-than-wide	3
Margins	Irregular	2
	Extrathyroidal extension	3
Calcifications	Microcalcifications	3
	Macrocalcification	1

Final TI-RADS classification was determined according to the total score:

- **TR1:** 0 points (benign)
- **TR2:** up to 2 points
- **TR3:** 3 points
- **TR4:** 4–6 points
- **TR5:** ≥ 7 points (high malignancy risk)

The study data were analyzed using SPSS version 26.0. The following statistical parameters were calculated:

- Accuracy, sensitivity, specificity
- Positive predictive value (PPV)
- Negative predictive value (NPV)
- χ^2 test
- ROC curve analysis

A p value < **0.05** was considered statistically significant.

RESULTS

A total of 126 patients were included in the study. Their main demographic characteristics are presented in the table below.

Table 1. Demographic characteristics of participants

Indicator	Mean $\pm$ SD / n (%)
Number of patients	126
Age (years)	47.2 $\pm$ 11.6
Females	98 (77.7%)
Males	28 (22.3%)
Nodule size (mm)	8.6 – 32.4 mm (mean 17.8 $\pm$ 6.2 mm)

Nodules were evaluated using the ACR TI-RADS classification and categorized into TR1–TR5 groups.

Table 2. Distribution of nodules by TI-RADS categories

TI-RADS category	Number of patients (n)	Percentage (%)
TR1	8	6.3%
TR2	22	17.5%
TR3	31	24.6%
TR4	38	30.1%
TR5	27	21.4%

These results indicate that malignancy risk is higher in the TR4–TR5 categories.

FNAB was performed in 89 patients. The cytological findings were distributed as follows:

Table 3. FNAB results (Bethesda classification)

Bethesda category	Number (n)	Percentage (%)
I – Non-diagnostic	6	6.7%
II – Benign	51	57.3%
III – AUS/FLUS	11	12.3%
IV – Follicular neoplasm	8	9.0%
V – Suspicious for malignancy	5	5.6%
VI – Malignant	8	9.0%

Comparison of TI-RADS categories with cytological/histological results showed the following relationship:

Table 4. TI-RADS category and malignancy rate

TI-RADS	Total nodules (n)	Malignant (n)	Malignancy rate (%)
TR1	8	0	0%
TR2	22	1	4.5%
TR3	31	2	6.4%
TR4	38	9	23.7%
TR5	27	13	48.1%

The highest malignancy rate was observed in the TR5 category (48.1%).

Statistical analysis yielded the following results:

Table 5. Diagnostic performance of the TI-RADS system

Indicator	Result
Sensitivity	88.5%
Specificity	72.4%
PPV (Positive predictive value)	43.2%
NPV (Negative predictive value)	95.1%
AUC (Area under ROC curve)	0.87

The TI-RADS system reliably identifies benign nodules (NPV 95.1%) and demonstrates high sensitivity in detecting malignant nodules.

DISCUSSION

The results of this study demonstrate that the TI-RADS system, based on ultrasound criteria, possesses a high level of diagnostic effectiveness in assessing the risk of malignancy in thyroid nodules. The findings are consistent with data reported in international literature, further confirming the relevance of implementing this system in clinical practice.

In this study, the malignancy rates in the TR4 and TR5 categories were 23.7% and 48.1%, respectively. These values closely align with the statistics reported by the authors who developed the ACR TI-RADS system, where the malignancy risk for TR5 nodules ranges between 50–70%. The absence of malignancy or its extremely low rate in the TR1 and TR2 categories further confirms that classifying these nodules as benign is appropriate. This, in turn, indicates that the TI-RADS system helps avoid unnecessary biopsies in benign cases.

When compared with FNAB (Bethesda) results, a significant correlation was identified between TI-RADS categories and malignancy, with the system demonstrating a sensitivity of 88.5% and a specificity of 72.4%. Notably, the very high negative predictive value (95.1%) allows for safe follow-up in benign nodules. These results imply that TI-RADS contributes to reducing the number of biopsies performed on benign nodules, which is clinically and economically advantageous.

The study also confirmed that microcalcifications, a “taller-than-wide” shape, marked hypoechogenicity, and irregular margins are the strongest ultrasound predictors of malignancy. These

features correspond well with the major malignancy criteria described in international guidelines (ATA, ACR, ETA). Additionally, supplementary techniques such as Doppler imaging and elastography provided further information regarding nodule stiffness and vascular characteristics, enhancing overall diagnostic accuracy.

Another important finding of the study is that the TI-RADS system reduces interobserver variability. Its standardized scoring system promotes a unified approach among clinicians and minimizes diagnostic errors, which is particularly valuable for less-experienced radiologists.

However, some limitations of the study must also be acknowledged. These include the relatively limited number of participants, the use of data from a single center, and the lack of histological verification in all nodules, which may restrict the generalizability of the findings. Despite these limitations, the available data support the practical significance of the TI-RADS system.

Overall, the results indicate that the TI-RADS system is an effective diagnostic tool for identifying nodules with a high risk of malignancy while reducing unnecessary invasive procedures in benign cases.

CONCLUSION

In this study, the clinical effectiveness of modern ultrasound diagnostics and the TI-RADS system in assessing the risk of malignancy in thyroid nodules was evaluated. The findings demonstrated that the TI-RADS classification has high sensitivity (88.5%) and satisfactory specificity (72.4%) in differentiating malignant and benign nodules. Notably, the high negative predictive value (95.1%) allows for the safe follow-up of benign nodules without the need for unnecessary invasive procedures. The proportion of malignant cases in TR4 and TR5 categories—23.7% and 48.1%, respectively—confirms the clinical significance of the TI-RADS system in identifying malignant nodules. Additionally, microcalcifications, marked hypoechogenicity, a “taller-than-wide” shape, and irregular margins were identified as the most reliable ultrasound features associated with malignancy.

The results of the study suggest that the TI-RADS system helps optimize the need for biopsy, reduces the number of unnecessary invasive procedures, and ensures a standardized approach during the diagnostic process. This system can serve as a reliable diagnostic guide for endocrinologists, radiologists, and surgeons in clinical practice.

Overall, incorporating the TI-RADS system into widespread clinical use contributes to the standardization of malignancy risk assessment in thyroid nodules, enhances diagnostic accuracy, and improves the quality of medical care provided to patients.

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