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Role of Sonography in Characterization of Thyroid Nodules and Differentiation as Benign or Malignant

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Abstract

Background: Thyroid nodules are a common finding in clinical practice, increasingly detected due to the widespread use of high-resolution ultrasound. Although most nodules are benign, a significant minority may be malignant, necessitating a reliable triage strategy to determine which nodules require further intervention. The American College of Radiology Thyroid Imaging Reporting and Data System (ACR TIRADS) offers a structured risk stratification system based on sonographic features.

Objective: This study aims to evaluate the diagnostic performance of ultrasound-based TIRADS classification in distinguishing benign from malignant thyroid nodules. A conservative approach was adopted by classifying TIRADS III lesions as "suspicious," in addition to the usual IV and V categories. This protocol was designed to maximize sensitivity, especially in a real-world setting with variable follow-up.

Methods: This was a prospective observational study conducted in the Department of Radiodiagnosis, MGM Medical College, Kamothe, Navi Mumbai, between January and May 2025. In each patient, the most suspicious nodule (highest TIRADS score) was evaluated. Final diagnoses were based on histopathological results or CT imaging where pathology was unavailable. Statistical analysis was conducted to determine sensitivity and specificity.

Results: Out of 30 patients, 13 were confirmed malignant and correctly classified as suspicious (TIRADS III–V), yielding a sensitivity of 100%. Seven nodules were falsely labeled suspicious but were benign on final diagnosis, resulting in a specificity of 58.82%. The negative predictive value was 100%, and there were no false negatives.

Conclusion: Ultrasound using ACR TIRADS is a highly sensitive tool for evaluating thyroid nodules. Including all TIRADS III as suspicious improves malignancy detection and eliminates false negatives, albeit with a trade-off in specificity. This protocol is especially suited for conservative screening in resource-limited or high-risk patient populations.

Keywords: Thyroid nodules; Ultrasonography; TI-RADS; Fine needle aspiration cytology; Thyroid malignancy; Risk stratification

Introduction

Thyroid nodules represent one of the most frequently encountered abnormalities in neck imaging. Their detection rate has sharply increased with the proliferation of high-resolution ultrasound, which can identify nodules in up to 67% of asymptomatic individuals[1]. While only 5–15% of thyroid nodules are malignant[2], the sheer prevalence of nodules creates a diagnostic challenge: how to accurately identify malignancies without overburdening the healthcare system with unnecessary biopsies and surgeries.

Fine needle aspiration cytology (FNAC) remains the gold standard for evaluating thyroid nodules. However, performing FNAC for every incidentally detected nodule is neither practical nor cost-effective. To address this, the American College of Radiology introduced the TIRADS (Thyroid Imaging Reporting and Data System), which standardizes the assessment of nodules based on sonographic features: composition, echogenicity, margins, shape, and echogenic foci[3]. Based on a cumulative point system, nodules are categorized from TIRADS 1 (benign) to TIRADS 5 (highly suspicious for malignancy).

The TIRADS system is widely validated and improves interobserver consistency. However, the classification of TIRADS III nodules—those with "mildly suspicious" features—remains debatable. Multiple studies report that 5–10% of TIRADS III lesions may be malignant [4,5]. Despite this, many protocols reserve FNAC for TIRADS IV and V nodules only, potentially leading to missed diagnoses. Conversely, a safety-first approach might treat even TIRADS III nodules as suspicious, improving sensitivity but lowering specificity.

In this study, we adopted a conservative classification—grouping TIRADS III, IV, and V as suspicious—to evaluate its impact on diagnostic performance. This approach was especially chosen to reflect real-world conditions in a tertiary Indian setup, where follow-up and access to biopsy may be inconsistent. Our primary aim was to assess whether this strategy could improve detection rates and eliminate false negatives, thereby enhancing patient safety. To this end, we analyzed 30 consecutive thyroid ultrasound cases from January to May 2025, correlating the highest TIRADS score per patient with histopathological or CT-confirmed diagnoses.

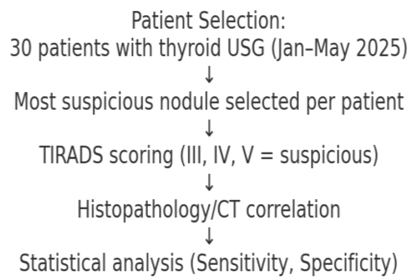
ACR TIRADS Scoring System

Feature	Scoring Criteria
Composition	Cystic/Spongiform (0), Mixed (1), Solid (2)
Echogenicity	Anechoic (0), Hyperechoic/Isoechoic (1), Hypoechoic (2), Very Hypoechoic (3)
Shape	Wider-than-tall (0), Taller-than-wide (3)
Margin	Smooth (0), Ill-defined (0), Lobulated/Irregular (2), Extrathyroidal extension (3)
Echogenic Foci	None (0), Large comet-tail (0), Macrocalcifications (1), Peripheral calcifications (2), Microcalcifications (3)

Patient Demographics

Parameter	Value
Total patients	30
Male	8

Female	22
Mean age (years)	46.2
Age range (years)	22–72



Materials and Methods

This was a prospective observational study conducted in the Department of Radiodiagnosis, MGM Medical College, Kamothe, Navi Mumbai, between January and May 2025.

Patient Selection

Thirty patients with thyroid lesions identified on ultrasound between January and May 2025 were included. The most suspicious nodule per patient was selected based on sonographic features. All patients underwent high-resolution USG, and findings were correlated with histopathology (FNAC or biopsy) or CT where pathology was unavailable.

Inclusion criteria

1. Patients undergoing high-resolution thyroid ultrasonography within the study period. 2. Availability of definitive diagnosis through histopathology (FNAC or surgical biopsy) or CT correlation.
2. Complete demographic and clinical data.

Exclusion criteria

a) Nodules lacking histopathological or definitive imaging confirmation.
b) Poor quality ultrasound images due to patient habitus or motion artefacts.
c) Cases with incomplete follow-up.

Ultrasound Protocol

- Equipment: Samsung RS85 with 5–12 MHz linear probe.
- Patient position: Supine with neck extended using a pillow under shoulders.
- Imaging: Transverse and longitudinal scans of both lobes and isthmus.
- Evaluation: Nodules assessed for composition, echogenicity, shape, margins, and echogenic foci as per ACR TIRADS.
- Doppler Assessment: Performed in all nodules to assess vascularity pattern.
- Elastography: Performed where feasible to assess stiffness qualitatively.

Classification

TIRADS III, IV, and V were considered suspicious for malignancy.

Only the most suspicious nodule in each patient was selected for analysis.

Statistical Analysis

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated using standard formulae.

In instances with multiple nodules, the lesion with the highest TIRADS score (i.e., most suspicious) was selected for analysis. TIRADS III, IV, and V lesions were classified as “suspicious.” Each case was subsequently categorized into one of four diagnostic outcomes: true positive, true negative, false positive, or false negative, and sensitivity and specificity were calculated accordingly.

TIRADS III, IV, and V lesions were classified as “suspicious.” Histopathological reports (FNAC/surgical biopsy) were considered the diagnostic gold standard. In patients without pathology reports, CT findings were accepted as definitive. Each case was categorized into one of four outcomes: true positive (TP), true negative (TN), false positive (FP), or false negative (FN).

Results

Out of 30 patients:

- 13 were true positives (TIRADS III–V with malignancy on pathology/CT)
- 10 were true negatives (non-suspicious on USG and benign on pathology)
- 7 were false positives (TIRADS III–V but benign)
- No false negatives were recorded

This translated to:

- Sensitivity: 100%
- Specificity: 58.82%
- Total malignancies detected: 13/30 (43.3%)

Example Case:

A 60-year-old female with a 2.1x2.6x2.9 cm TIRADS IV nodule (solid-cystic, hyperechoic, punctate echogenic foci) (Fig. 1), was confirmed to have a non-invasive follicular thyroid neoplasm with papillary-like features, supporting the sonographic suspicion.

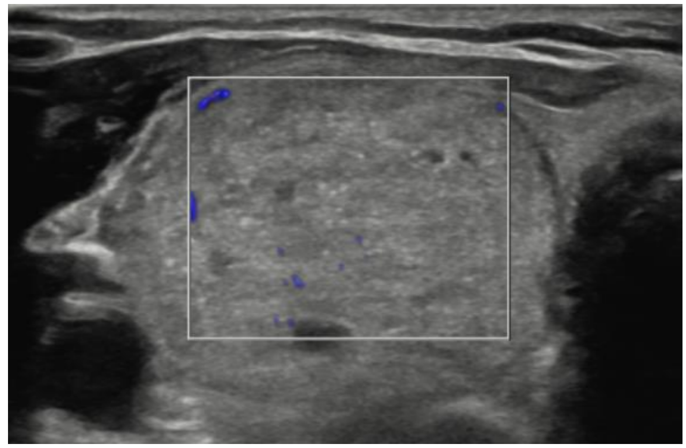
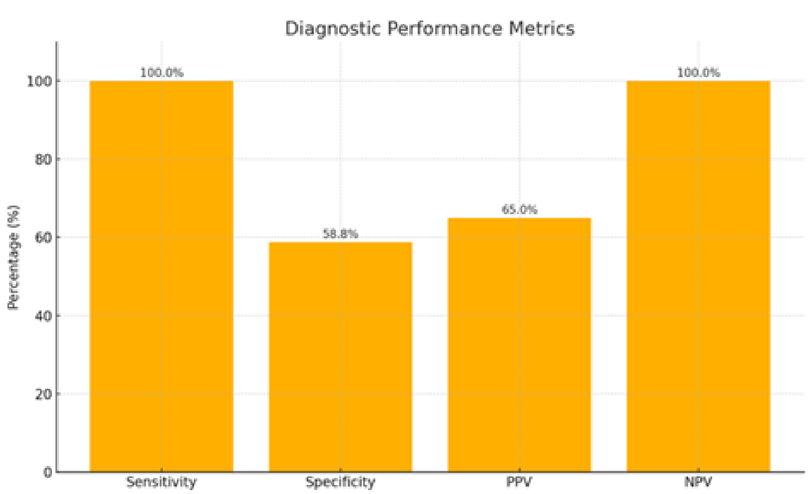


Figure 1: Follicular thyroid neoplasm-TIRADS IV nodule

Distribution of TIRADS Categories

TIRADS Category	Number of Nodules
TR1	0
TR2	0
TR3	8
TR4	14
TR5	8

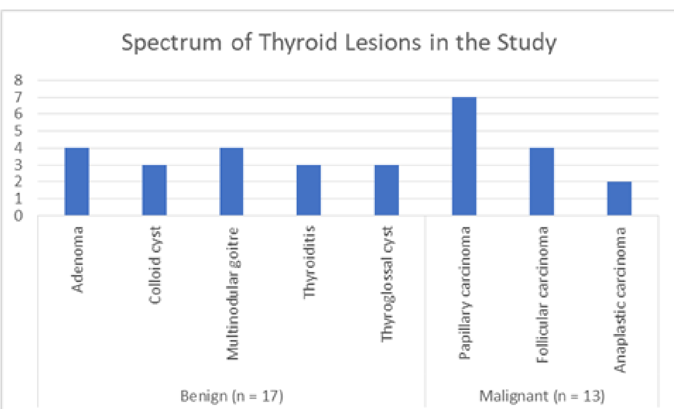
Graph 1:



Spectrum of Thyroid Lesions in the Study (n = 30)

Category	Lesion Type	Number of Cases (n = 30)	Typical Ultrasound Features
Benign (n = 17)	Adenoma	4	Solid, iso/hyperechoic lesion with smooth margin and peripheral vascularity
	Colloid cyst	3	Anechoic or mixed lesion with comet-tail artifact and thin, well-defined wall
	Multinodular goitre	4	Multiple nodules of variable echogenicity, areas of cystic degeneration, well-circumscribed margins
	Thyroiditis	3	Diffuse heterogeneous echotexture, hypoechogenicity, and increased vascularity on Doppler
	Thyroglossal cyst	3	Midline cystic lesion, anechoic with thin wall, no internal vascularity
Malignant (n = 13)	Papillary carcinoma	7	Solid hypoechoic nodule with microcalcifications, irregular margins, and taller-than-wide shape
	Follicular carcinoma	4	Solid hypoechoic/isoechoic lesion with smooth margins, peripheral halo, and internal vascularity
	Anaplastic carcinoma	2	Heterogeneous, ill-defined infiltrative mass with areas of necrosis and loss of thyroid architecture

Graph 2:



Discussion

The study included a wider variety of benign entities such as colloid cysts, multinodular goitre, thyroiditis, and thyroglossal cysts, along with malignant types including papillary, follicular, and anaplastic carcinoma. Our findings reinforce the high sensitivity of USG when interpreted using the ACR TIRADS framework. By classifying TIRADS III nodules as suspicious, no malignancies were missed, ensuring a sensitivity and NPV of 100%.

While specificity decreased to 58.82%, this trade-off is acceptable in settings where patient follow-up is uncertain, as is often the case in India.

Comparisons with Literature

- Zhao et al. (2020) demonstrated a malignancy rate of 8.7% in TIRADS III lesions, supporting their inclusion in biopsy protocols.
- Choi et al. (2020) reported similar improvements in sensitivity when TIRADS III was treated as suspicious.
- Our results align with Moon et al. (2008) and Russ et al. (2013), who also identified solid composition, hypoechogenicity, and microcalcifications as the strongest predictors of malignancy.

Clinical Implications in India

In Indian tertiary setups, logistical and financial barriers may delay or prevent follow-up imaging or biopsy.

A conservative approach that maximizes early detection is preferable, even at the cost of increased false positives.

Adjunct Techniques

Elastography and Doppler flow assessment can provide additional risk stratification. Increased stiffness on elastography and intranodular vascularity on Doppler correlate with malignancy, but their routine use is limited by availability. Most malignant nodules in our study shared sonographic traits consistent with previous findings: solid composition, hypoechogenicity, irregular margins, and punctate echogenic foci [6–8].

Sonographic Traits Common in Malignant Nodules

Feature	Frequency in Malignant Nodules (n=13)
Solid composition	12/13
Hypoechogenicity	11/13
Microcalcifications	10/13
Taller-than-wide shape	7/13
Irregular margins	6/13

Moreover, cases like [Patient] (TIRADS IV, medullary thyroid carcinoma) (Fig. 2) and [Patient] (TIRADS III/IV, papillary carcinoma) (Fig. 3) highlight that even mildly suspicious nodules can harbor aggressive histologies, further supporting the expanded suspicious criteria.

Our specificity (58.82%) is lower than some studies[9,10], which can be attributed to our inclusion of TIRADS III as a suspicious category. However, this strategy may be justifiable in resource-limited settings where follow-up imaging and patient compliance are inconsistent.

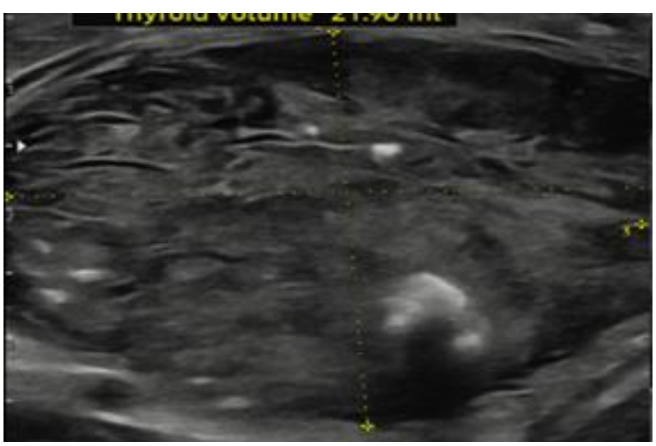


Figure 2: TIRADS IV, medullary thyroid carcinoma

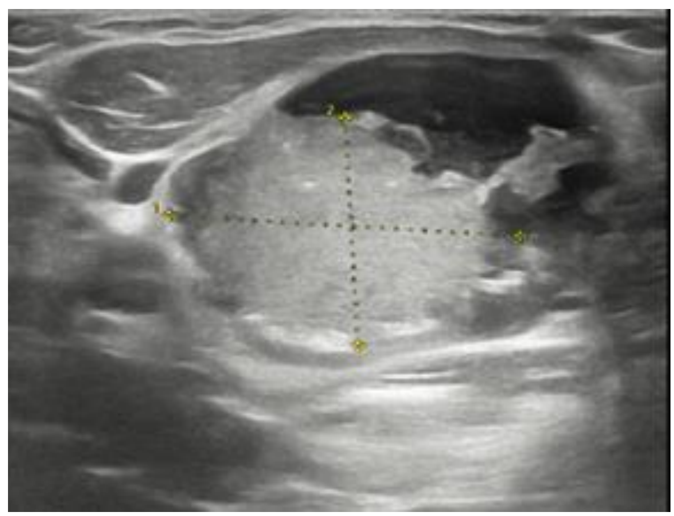


Figure 3: TIRADS IV, papillary carcinoma

Strengths and Limitations

Strengths

- 100% sensitivity achieved with modified TIRADS criteria.
- Use of histopathology or CT as the gold standard ensures robust outcome classification.

Limitations

- Small sample size limits generalizability.
- Retrospective design; possible selection bias.
- Lack of uniform elastography data for all nodules.
- Single-center study; interobserver variability not assessed.

Conclusion

This study reaffirms the critical role of high-resolution ultrasonography, particularly when interpreted through the ACR TIRADS framework, in the evaluation of thyroid nodules. By including TIRADS III lesions in the suspicious category, we achieved a sensitivity of 100%, thereby eliminating false negatives and ensuring that no malignant nodule was overlooked. Although this strategy led to a moderate reduction in specificity (58.82%), the trade-off is justifiable in clinical scenarios where early detection of malignancy is paramount and patient follow-up may be inconsistent.

In resource-constrained or high-risk settings, where the cost of a missed malignancy can be severe, a safety-first approach that tolerates a higher rate of false positives is preferable. Furthermore, this approach aligns with current global trends toward conservative yet comprehensive screening protocols. The ability of sonographic features—such as solid composition, hypoechogenicity, irregular margins, and punctate echogenic foci—to stratify malignancy risk has once again been validated in this study.

This work also underscores the value of contextual flexibility in radiologic protocols. While guidelines provide structure, real-world modifications based on clinical judgment, local resources, and patient demographics are essential. Future studies with larger sample sizes, long-term follow-up, and integration of adjunct modalities like elastography and molecular testing can further enhance the diagnostic algorithm.

In conclusion, ultrasound remains an indispensable, frontline tool in thyroid cancer screening. A vigilant interpretation of TIRADS III–V lesions significantly improves malignancy detection rates and ensures that radiologists fulfill their essential role in early cancer diagnosis and patient safety.

Abbreviations

ACR – American College of Radiology
ATC – Anaplastic Thyroid Carcinoma
CT – Computed Tomography
FN – False Negative
FNAC – Fine Needle Aspiration Cytology
FP – False Positive
FTC – Follicular Thyroid Carcinoma
MHz – Megahertz
MNG – Multinodular Goitre
NPV – Negative Predictive Value
PPV – Positive Predictive Value
PTC – Papillary Thyroid Carcinoma
TI-RADS – Thyroid Imaging Reporting and Data System
TN – True Negative
TP – True Positive
US – Ultrasound
USG – Ultrasonography

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