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Diagnostic performance of ACR-TIRADS ultrasound lexicon in risk stratification of thyroid nodules

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ABSTRACT

Background: Thyroid nodules (TNs) are commonly encountered in clinical settings. Many professional organizations have adopted and published ultrasound-based risk stratification systems (RSSs) as a tool for standardized reporting and evaluation. The American College of Radiology-Thyroid Imaging Reporting and Data System (ACR-TIRADS) Committee in 2017 proposed a white paper with a novel risk stratification system that classifies TNs into 5 morphologic categories on the basis of their ultrasonographic features (echogenicity, composition, margin, shape, and echogenic foci). These features are described and assigned points to obtain a total score that determines the thyroid nodule's TR risk levels (from TR1 to TR5).

Objective: The aim of the current study was to assess the value of the ACR Thyroid Imaging Reporting and Data System (ACR-TIRADS) Lexicon in predicting the nature of different thyroid nodules.

Patients and methods: A total of 102 subjects (90 female and 12 males; age between 18 and 77 years) with 130 thyroid nodules with a definitive cytopathologic diagnosis on the basis of US-guided FNAB and/or surgery results were enrolled. The mean age was 41.03 (SD 13.09) years, with ages ranging between 18 and 77 years. Our study was carried out between November 2020 and October 2022.

Result: The ACR-TIRADS US lexicon's predictive ability in thyroid nodules' risk stratification was assessed. The overall accuracy, sensitivity, specificity, NPV, and PPV were 83.08%, 94.34%, 75.32%, 95.08% and 72.46%, respectively.

Conclusions: In everyday practice, ACR-TIRADS classification is a non-invasive, safe, reliable, and applicable tool for evaluating thyroid nodules, standardizing report structure, and reducing inconsistencies with thyroid nodules' interpretation.

Keywords: ACR TIRADS lexicon, Thyroid nodules, Cytopathology, Malignancy risk, Diagnostic accuracy.

INTRODUCTION

Thyroid nodules (TNs) are frequently encountered in clinical settings, with a prevalence of 19% to 70% on ultrasound (US) assessment, a higher female incidence, and only ~ 5% of all thyroid nodules harboring malignancy. Thyroid cancer incidence is expanding annually, and it is anticipated to end up as the 4th leading type of cancer worldwide. Thyroid cancer in Egypt is considered to be the 6th most common malignancy among Egyptian ladies and the 7th among Egyptian men [(1-3)].

Given that ultrasound is the 1st line imaging modality for the assessment of thyroid nodules, numerous professional organizations have adopted ultrasound-based RSSs to evaluate thyroid nodules' malignancy risk on the basis of US characteristics (either point-based or pattern-based approaches) [(4)].

The TIRADS lexicon was originally proposed in 2009 by Horvath *et al.*, followed by several modifications on the basis of clinical practice. In 2017, the American College of Radiology (ACR) published a score-based, easily applicable approach called the ACR Thyroid Imaging Reporting and Data System (TIRADS), on the basis of the Breast Imaging Reporting and Data System (BIRADS) model [(5,6)].

Every nodule is described and allocated points based on 5 US characteristics (echogenicity, composition, margin, shape, and echogenic foci), and these points are added up to obtain a total numeric score, resulting in a final risk level from TR1 to TR5. Depending on the nodule's ACR-TIRADS risk category and maximum dimension, FNA or ultrasound follow-up is advised [(7-9)].

ACR TIRADS was found to be superior to other RSSs in terms of reducing the number of unnecessary FNAs and raising diagnostic accuracy [(10)].

The aim of the current study was to assess the value of the ACR Thyroid Imaging Reporting and Data System (ACR-TIRADS) Lexicon in predicting the nature of different TNs.

PATIENTS AND METHODS

Patient's demographic data:

A total of 102 subjects (90 female and 12 male; age between 18 and 77 years) with 130 TNs with a definitive cytopathologic diagnosis on the basis of US-guided FNAB and/or surgery results were enrolled (**Figure 1**). Our study was carried out between November 2020 and October 2022.

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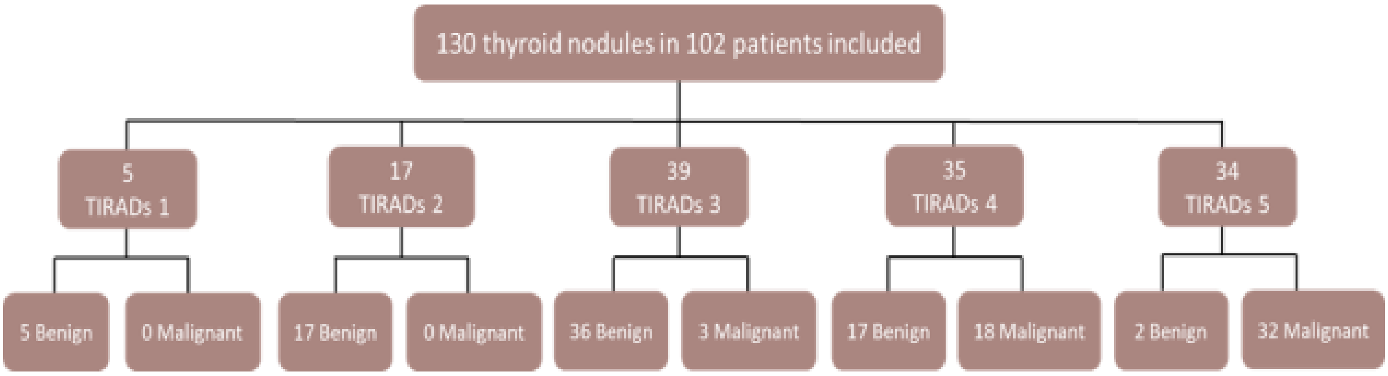

Figure (1): Flowchart showing the study participants.

Inclusion criteria: Patients above 18 years, referred for neck US and found to have TNs, and referred for FNAC on physician request or underwent subsequent surgical excision.

Exclusion criteria: Patients below 18 years, recent biopsy was done, and no available histopathological reports.

Technique: Ultrasound scan of all TNs was performed using a 7.5–10 MHz linear transducer (Aplio 500, LOGIQ P7 and P9 systems). Ultrasound examination was done with the patient lying on his back, his neck somewhat overextended by a pillow beneath his shoulders. The scanning protocol in all examined cases included both longitudinal as well as transverse TNs' real-time imaging using illustrative DICOM viewer images.

Image interpretation (Figure 2)**:** All TNs were characterized in terms of their composition, echogenicity, shape, margin, and presence of different types of echogenic foci. The ACR-TIRADS classification was used to assign points [6,11].

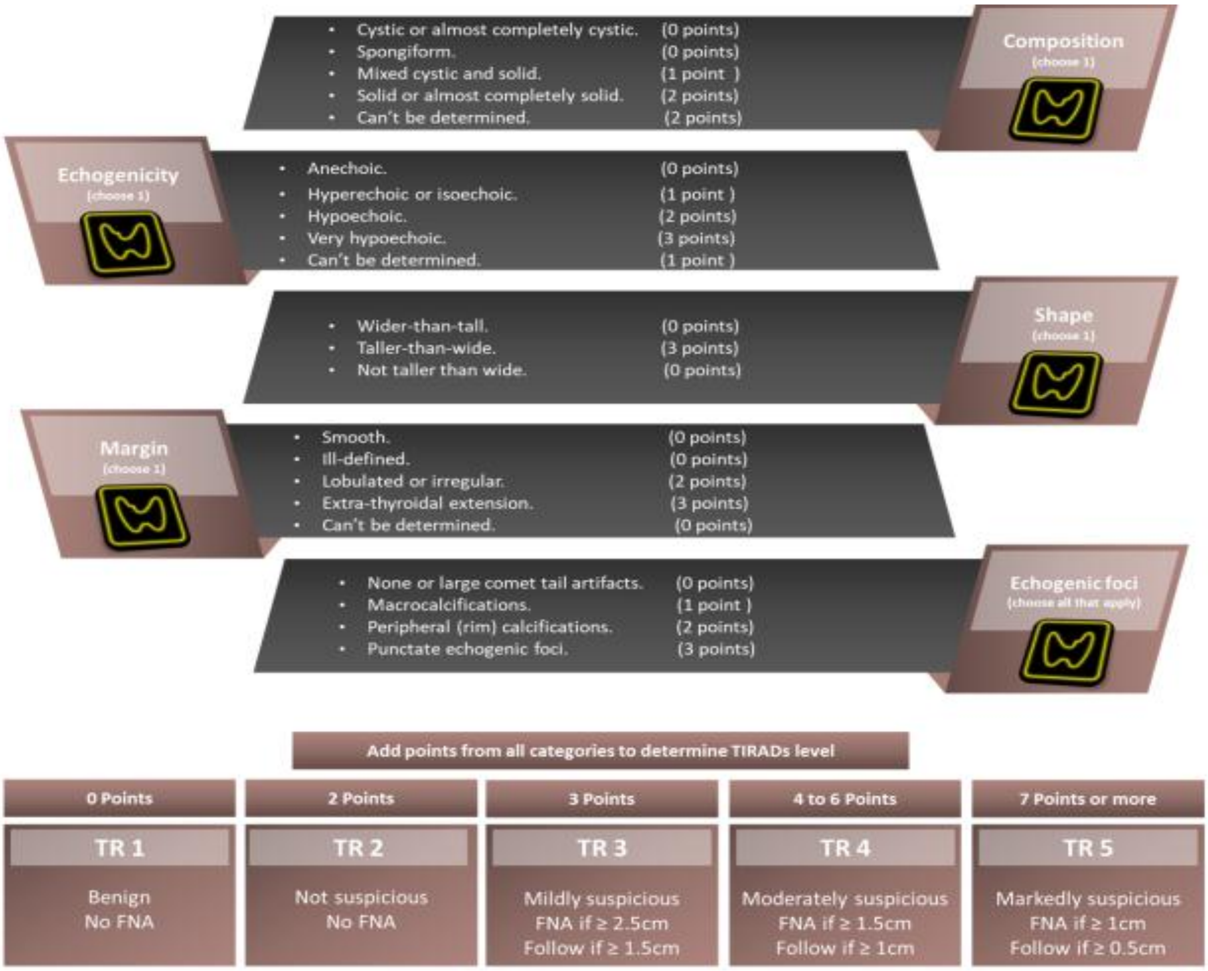

Figure (2): ACR-TIRADS image interpretation.

Final diagnosis: The results of the cytopathological and/or histopathological examinations were considered our standard reference.

Ethical approval:

This study was ethically approved by the Institutional Review Board [IRB] of the Faculty of Medicine, Mansoura University. Written informed consent was obtained from all participants. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

***Statistical analysis**:*

IBM SPSS software, version 27, was used to input data into the computer for processing. The risk of malignancy was calculated for sonographic elements and TIRADS levels. ACR-TIRADS overall accuracy, sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were estimated.

RESULTS

The mean age was 41.03 (SD 13.09) years; median age 40 years, ranging between 18 and 77.

102 patients were referred from the surgical clinic with a clinical or radiological diagnosis of TNs. Out of the 130 TNs, 77 (59.2%) turned out to be benign and 53 (40.8%) turned out to be malignant (**Table 1**).

Table (1): Analysis of the nature of the nodules according to the final pathological diagnosis

Variable	Nodules (N= 130)	
Nature of the nodules	Number	Percent (%)
Benign	77	59.2 %
Malignant	53	40.8 %

Concerning TNs, US characteristics, hypoechogenicity, taller-than-wide orientation, ETE, and punctuate echogenic foci are significantly associated with malignancy (**Table 2**).

Table (2): Ultrasound characteristics of the nodules on the basis of their nature (benign / malignant) and malignancy risk.

Characteristics	*Benign (77)*	*Malignant* (53)	*Total*	*Risk of malignancy*	*Test of significance*
Composition					
Solid	*50*	*52*	*102*	*50.9%*	*MC = 20.480 P < 0.001**
Cystic	*2*	*0*	*2*	*0%*	
Mixed cystic and solid	*22*	*1*	*23*	*4.3 %*	
Spongiform	*3*	*0*	*3*	*0%*	
Echogenicity					
Isoechoic	*64*	*14*	*78*	*17.9%*	*MC = 52.452 P < 0.001**
Hypoechoic	*9*	*37*	*46*	*80.4%*	
Very hypoechoic	*0*	*2*	*2*	*100%*	
Hyperechoic	*2*	*0*	*2*	*0%*	
Anechoic	*2*	*0*	*2*	*0%*	
Shape					
Taller than wider	*0*	*9*	*9*	*100%*	*MC = 14.048 P < 0.001**
Wider than taller	*77*	*44*	*121*	*36.4%*	
Margins					
Smooth	*73*	*23*	*96*	*24%*	*MC = 47.342 P < 0.001**
Irregular/lobulated	*3*	*14*	*17*	*82.4%*	
Extra thyroid extension	*0*	*16*	*16*	*100%*	
Ill defined	*1*	*0*	*1*	*0%*	
Echogenic foci					
None	*54*	*21*	*75*	*28%*	*MC = 39.591 P < 0.001**
Punctuate echogenic foci	*1*	*19*	*20*	*95%*	
Rim of calcification	*6*	*2*	*8*	*25%*	
Macro calcification	*8*	*6*	*14*	*42.9%*	
Large comet tail artifact	*6*	*0*	*6*	*0%*	
PEF and Macro calcification	*1*	*5*	*6*	*83.3%*	
Rim and Macro calcification	*1*	*0*	*1*	*0%*	

Our study showed that the highest malignancy risk was among the TIRADS 4 and TIRADS 5 categories, with percentages of 51.4% and 94.1%, respectively (**Table 3**).

Table (3): Correlation between TIRADs and nodular pathology with malignancy risk in each TR category.

TIRADs categories	Nature		Risk of malignancy	Test of significance
	Benign (n= 77)	Malignant (n= 53)		
1	5 (6.5%)	0 (0%)	0%	MC= 74.532 P <0.001*
2	17 (22.1%)	0 (0%)	0%	
3	36 (46.7%)	3 (5.7%)	7.7%	
4	17 (22.1%)	18 (34%)	51.4%	
5	2 (2.6%)	32 (60.3%)	94.1%	

*: significant value <0.05.

Our study showed high overall diagnostic accuracy for the ACR-TIRADS (Table 4; Figure 3).

Table (4): Predictive ability of TIRADS score to detect the occurrence of malignancy.

TIRADS categories	P value	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
TIRADS 1	0.005*	0	100	100	0	100
TIRADS 2	<0.001*	0	100	100	0	100
TIRADS 3	<0.001*	0	100	92.3	0	92.3
TIRADS 4	0.133	100	0	51.4	51.4	0
TIRADS 5	<0.001*	100	0	94.1	94.1	0
Combined		94.34	75.32	83.08	72.46	95.08

*: significant value <0.05.

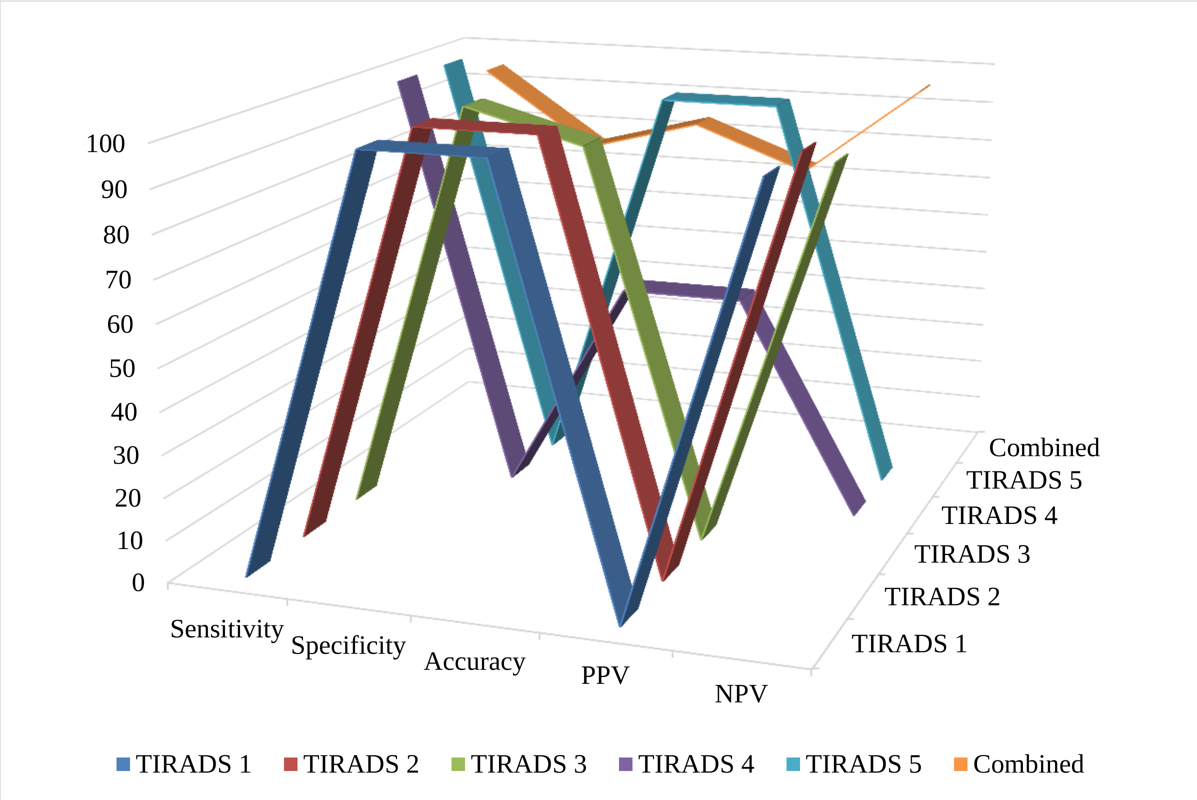

Figure (3): Predictive ability of the ACR-TIRADS score to detect the occurrence of malignancy.

CASE PRESENTATION

Case No. (1)

Presentation: A 27-year-old female presented with neck swelling. US was performed.

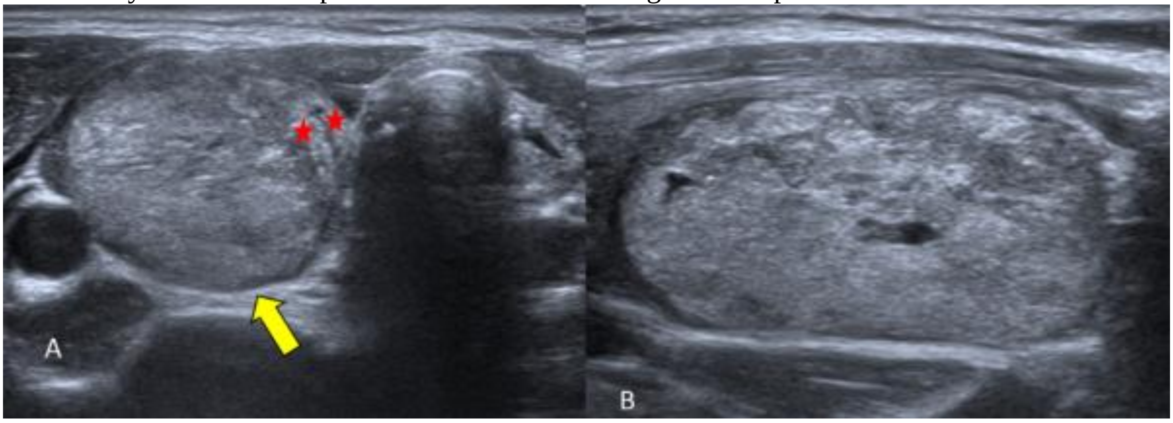

Figure (4): (A) Transverse and (B) longitudinal scans of right thyroid lobe follicular adenoma.

Ultrasonographic features of the nodule according to ACR-TIRADs lexicon (Figure 4):

(A) Transverse and (B) longitudinal scans of right thyroid lobe showing nodule with the following criteria:

Variable	US descriptor	Points
Composition	Solid	2
Echogenicity	Isoechoic "red stars"	1
Shape	Wider-than-tall	0
Margin	Smooth "well-defined", "yellow arrow"	0
Echogenic foci	No punctate echogenic foci.	0
Total points		**3**

TIRADS categorization: TIRADS (3).

Size of the nodule: (18x23x35.5mm) AP x T x H respectively. **Pathology: Follicular adenoma.**

Case No. (2)

Presentation: A 34-year-old female presented with neck swelling. US was performed.

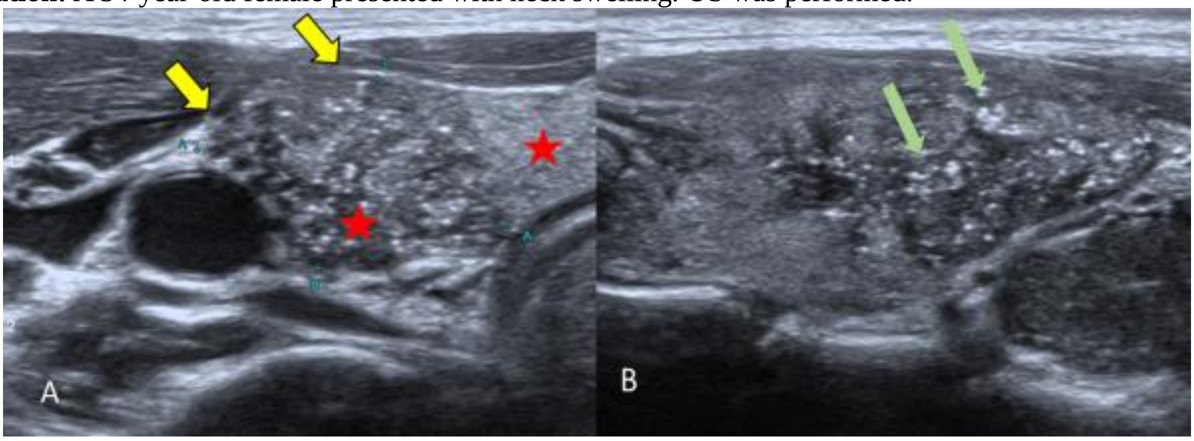

Figure (5): (A) Transverse and (B) longitudinal scans of right thyroid lobe PTC.

Ultrasonographic features of the nodule according to ACR-TIRADs lexicon:

Figure (5): (A) Transverse and (B) longitudinal scans of right thyroid lobe showing nodule with the following criteria:

Variable	US descriptor	Points
Composition	Solid.	2
Echogenicity	Hypoechoic "red stars"	2
Shape	Wider-than-tall	0
Margin	Extra-thyroid extension "yellow arrows"	3
Echogenic foci	Punctate echogenic foci "green arrows"	3
Total points		**10**

TIRADS categorization: TIRADS (5).

Size of the nodule: (12 x19.5 x 25mm) AP x T x H respectively. **Pathology: Papillary thyroid carcinoma.**

DISCUSSION

The American Thyroid Association (ATA) defines a thyroid nodule as a discrete, 3-dimensional thyroid lesion that is radiologically differentiated from the adjacent normal thyroid parenchyma [8,12].

Our study was conducted on 130 TNs; 77 nodules (59.2%) out of them were benign, and 53 (40.8%) nodules were malignant. These results are also evident in **McClean *et al.*** [13] study**,** which applied to 308 nodules; the majority of them had a benign nature (56.2%, n= 173 nodules), and malignant nodules were found in (43.8%, n=135).

The ACR-TIRADS is a TN pattern-based RSS in which nodules are assessed in 5 US categories: composition, echogenicity, shape, margin, and echogenic foci. The radiologist shall allocate a single ultrasound feature for each of the 1st four categories and all features that can be applied to the 5th one. In each category, US characteristics are assigned a specific number of points according to their risk of malignancy, ranging from 0 to 3. The points are added up to place the nodule in one of the final 5 ascending risk levels (TR1 to TR), with TR1 being benign, TR2 being not suspicious, TR3 being mildly suspicious, TR4 being moderately suspicious, and TR5 being highly suspicious. Depending on the nodule's ACR-TIRADS risk category and maximum dimension, FNA or ultrasound follow-up is advised [14-17].

Regarding composition, in accordance with the current findings, **Xu *et al.*** [18] reported a 53.6% malignancy risk with solid nodules. In line with **Goel *et al.*** [19] who evaluated 46 spongiform nodules and found that none of these nodules revealed malignancy on cytology, we also found that all spongiform nodules were benign.

Regarding echogenicity, we found that very hypoechoic nodules carry a 100% risk of malignancy, with hypoechoic nodules coming after with a malignancy risk of 80.4%. Isoechoic nodules have a 17.9% malignancy risk, while neither anechoic nor hyperechoic nodules reveal malignancy. These results are comparable to **Rao *et al.*** [20] study who reported that very hypoechoic nodules had the highest risk of malignancy (100%), followed by hypoechoic nodules (61.5%) and isoechoic nodules (2.3%). Neither hyperechoic nor anechoic nodules were malignant (0% risk) [20].

Regarding shape, in the current study, most of the nodules are wider-than-tall (93.1%) and only (6.9%) are taller-than-wide; the latter have a 100% malignancy risk, while wider-than-tall nodules have a 36.4% malignancy risk. Our results coincide with **Azab *et al.*** [21] who mentioned that 100% of taller than wide nodules were malignant, and with **Xu *et al.*** [18] who reported that wider than tall nodules had a 34.9% malignancy risk.

Regarding margin, our study revealed that nodules with irregular/lobulated margins have 82.4% risk of malignancy and nodules with smooth margins have 24% risk of malignancy. In agreement with our results, **Barbosa *et al.*** [22] study provided that the risk of malignancy with irregular/lobulated and smooth margin nodules was 82.2% and 30.5%, respectively.

Extra-thyroid extension (ETE) is considered in several risk systems for thyroid cancer, including ours (ACR-TIRADS US lexicon), because it is a critical predictor of clinical outcomes in differentiated thyroid cancer (DTC) patients. [23]

In the present study, we found 16 nodules with extra-thyroid extension, and all of them revealed malignancy by pathology, confirming what other studies reported **Azab *et al.*** [21]**, Mohanty and Mishra** [24] and **Patil *et al.*** [25] where nodules with ETE had 100% malignancy risk**.**

Regarding echogenic foci, in the current study, we noticed that nodules with punctate echogenic foci (PEF) had the highest malignancy risk (95%). Similar results were informed by **Pei *et al.*** [26] as they stated that malignancy risk among TNs regarding echogenic foci was 96.2% for punctate echogenic foci.

In our study, nodules with large comet tail artifacts had a 0% risk of malignancy. This is supported by **Azab *et al.*** [21], and **Mohanty and Mishra** [24] who reported that none of the nodules with large comet tail artifacts were malignant.

Among all suspicious criteria of malignancy in this study, we found that numerous TNs' ultrasonographic characteristics are linked with an increased likelihood of malignancy. Very hypoechogenicity, ETE, taller than wide nodules, and PEF had a 100%, 100%, 100%, and 95% risk for malignancy, respectively. Within the same line, **Patil *et al.*** [25] mentioned that all nodules with marked hypoechogenicity and ETE had a 100% malignancy risk.

The current study showed an increased malignancy risk with an increasing nodule's ACR-TIRADS level. This comes in line with the studies done by **Qi *et al.*** [27] and **Araruna *et al.*** [28] in which a significant trend of a rising malignancy risk was noted as the final TR risk level gradually increased from TR1 to TR5.

Our study showed that the overall sensitivity, specificity, accuracy, PPV, and NPV of the ACR TIRADS US lexicon risk stratification system in predicting malignancy were 94.34%, 75.32%, 83.08%, 72.46%, and 95.08%, respectively, confirming what **Ruan *et al.*** [29] reported, as they mentioned similar values as regards sensitivity of 96.7%, specificity of 77.3%, accuracy of 84.9%, PPV of 73.3%, and NPV of 97.3%.

LIMITATIONS

- Some patients refused to be biopsied and didn't undergo surgical excision.
- FNA-related limitations include a considerable rate of inconclusive results and uncertain or indeterminate interpretations.

CONCLUSIONS

The ACR-TIRADS lexicon provides a non-invasive, valid, convenient, and easily applicable approach for thyroid nodules' assessment in routine practice. It provides a quantitative approach based on a point-allocation system for the description of each thyroid nodule, which helps unify reporting terms between clinicians and radiologists. Standardize report structure and content to reduce discrepancies in the thyroid nodules' interpretation. It can safely lower the number of unnecessary FNAs in a considerable proportion of benign thyroid nodules. We therefore advocate for the implementation of ACR-TIRADS categorization in the daily work of the radiologist and raising clinician awareness of the system.

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Competing interests: Nil.

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