

Surgeon Performed Ultrasound in Assessing Thyroid Nodule Using American College of Radiology Tirads and Total Malignancy Score (TMS): A Validation Cross Sectional Study.

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ABSTRACT

INTRODUCTION: This study aims to evaluate the diagnostic reliability of the American College of Radiology Thyroid Imaging Report and Data System (ACR-TIRADS) and Total Malignancy Score (TMS) scoring system, in differentiating benign and malignant thyroid nodules. **MATERIALS AND METHODS:** This is a cross-sectional study involving patients with thyroid nodules treated at Hospital Canselor Tuanku Muhriz from October 2017 until October 2019. Ultrasound findings were scored according to the ACR-TIRADS and TMS scoring system. They were then correlated with the FNAC or histopathology report. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy of both scoring system were calculated for analysis. **RESULTS:** A total of 150 patients with 223 thyroid nodules were included. 17% or 38 nodules were found to be malignant. The sensitivity, specificity, PPV, NPV and accuracy of ACR-TIRADS and TMS were 97.37% vs. 84.21%, 52.97% vs. 62.70%, 29.84% vs. 31.68%, 98.99% vs. 95.08% and 61% vs. 66% respectively. According to the ACR-TIRADS, only hypoechoic nodules was a strong predictor of malignancy. Comparatively, in the TMS, strong predictors of malignancy include single nodule, hypoechogenicity, irregular margin, and nodules with peri and intranodular vascularity. **CONCLUSION:** Both ACR-TIRADS and TMS score had good diagnostic accuracy in predicting malignant thyroid nodule. TMS is comparable and not inferior to ACR-TIRADS however, the latter is more practical for use as growth and Doppler characteristic are not included in the assessment.

Keywords

Thyroid nodule; Thyroid cytology; Thyroid malignancy; Thyroid ultrasound.

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Received: 26 February 2020 ; Accepted: 6 April 2021

Doi: <https://doi.org/10.31436/imjm.v20i3>

INTRODUCTION

Thyroid nodules are common. An estimated 19% - 67% of unsuspecting, healthy individuals have a detectable thyroid nodule on ultrasound.¹ Fortunately, the incidence of thyroid cancer is low, between 5% to 15% in the population.^{2,3,4} Differentiated thyroid cancer such as papillary and follicular thyroid cancer accounts for the majority of thyroid cancer.⁵ The incidence of thyroid cancer in Malaysia is 4.9/100000 populations.⁶

In the evaluation of a thyroid nodule, ultrasound is recommended as the first imaging tool.⁸ The widespread use of ultrasound has resulted in an increased rate of biopsy of thyroid nodules, commonly using the fine-needle aspiration for cytology (FNAC).⁷ It has become a challenge to correctly identify high-risk nodules for

biopsy. Subjecting all nodules to FNAC will not only burden the health care system in terms of cost but also cause unnecessary anxiety to patients.⁸

Therefore, appropriate sonographic criteria are needed to accurately classify these nodules and direct decision on biopsy, as well as avoiding unwarranted procedures. An effective classification system is practical and standardised. There are many studies and classification systems formulated that categorise thyroid nodules according to the risk of cancer.^{4,8,9,10} Existence of many such systems has led to confusion in understanding and also raises a question about its accuracy among radiologists and clinicians.

Two thyroid ultrasound classifications evaluated in this study are the American College of Radiology – Thyroid Image Reporting and Data System (ACR- TIRADS) and the Total Malignancy Score (TMS). ACR-TIRADS was developed by the American College of Radiology in 2017 and TMS is derived by a group of radiologists in Milan since 2013.^{11,12} Both of these systems use a pattern-oriented system for risk stratification and scores assigned to each feature.

The purpose of this study was to evaluate the diagnostic reliability of the Total Malignancy Score and ACR-TIRADS scoring system in differentiating benign and malignant thyroid nodules. Unique to this study is that the ultrasound was performed by an endocrine surgeon and not a radiologist. In this study, we described the sub-categories of these scoring system in predicting malignant thyroid nodules, as well as comparing the accuracy of both scores.

MATERIALS & METHODOLOGY

Ethical Consideration

Institutional review board approval was obtained for this cross-sectional study (UKM PPI/111/8/JEP-2019-125).

Study Population

This study was conducted in the Breast and Endocrine surgery unit of Universiti Kebangsaan Malaysia Medical Centre, Malaysia. Patient data were collected from the hospital database of thyroid patients from October 2017 to October 2019. The inclusion criteria were patients with thyroid nodules who had undergone FNAC or thyroidectomy. Patients with inconclusive cytology were excluded.

Thyroid Ultrasound

The thyroid ultrasound scans were performed by an endocrine surgeon with more than ten years of experience, using a General Electric Logic 9 E Pro ultrasound machine (GE Healthcare, Milwaukee, WI, USA) with a linear 5-12 MHz frequency probe. A pulse repetition frequency of 2400 Hz and a colour gain of

40%-50% were used for Doppler ultrasound, performed with a linear high-frequency probe (7.5-10 MHz).

Nodule Interpretation

For ACR-TIRADS, five features of a nodule were assessed; namely echogenicity, composition, shape, margin, and echogenic foci. A score was assigned for each feature and the added total score was used to classify nodules from TR1 (benign) to TR5 (highly suspicious). This is summarised in Table I.

In TMS classification, seven parameters were assessed; namely number of the nodule (solitary or multiple), structure (colloid or solid), echogenicity, halo, calcification, margin and colour flow. Growth was not included as the data were mostly not available. Again, a score was assigned for each ultrasound feature. The total score was added, and nodule categorised as TMS < 3, TMS = 3 and TMS >3 (Table I).

Data Analysis

Statistical analysis was performed using SPSS 25.0 software (SPSS Inc., Chicago, USA). All quantitative values were expressed as the median and interquartile range (IQR). Frequencies and percentages were used to summarise the categorical data. A simple logistic regression was used to determine the association between malignant nodule with each of the ultrasound characteristic, whereas the association with patients' demographic data were estimated using the Mann-Whitney U test.

Multiple logistic regression was performed for ultrasound features found to be statistically significant in the simple logistic regression as predictors of the final diagnosis. Adjusted odds ratios and their corresponding 95% confidence intervals were determined. MedCalc's online diagnostic test evaluation calculator was used to determine sensitivity, specificity and predictive values of ACR-TIRADS as well as TMS. Receiver Operating Characteristic (ROC) curve analysis and area under the curve (AUC) of TMS and ACR-TIRADS total score against malignant histopathology were determined. Statistical significance was set at $p < 0.05$.

Table I: American College of Radiology Thyroid Image Reporting and Data System (ACR-TIRADS) and Total Malignancy Score (TMS) system with their respective ultrasound feature and score.

ACR-TIRADS			Total Malignancy Score		
Variables	Characteristics	Score	Variables	Characteristic	Score
Echogenicity	Anechoic	0	Number	Multinodular	0
	Isoechoic or hyperechoic	1		Single Nodule	2
	Hypoechoic	2	Structure	Colloid	0
	Very hypoechoic	3			
Composition	Spongiform or completely cystic	0	Echogenicity	Non-hypoechoic	0
	Mixed solid and cystic	1		Hypoechoic	1
	Solid or almost completely solid	2	Halo	Continuous	0
Shape	Wider than taller	0		Discontinuous	1
	Taller than wider	3	Calcification	Macrocalcification	0
Margin	Smooth/ill-defined	0		Microcalcification	1
	Lobulated/irregular	2	Irregular		2
	Extrathyroidal	3			
Echogenic foci	None/comet tail artefact	0	Colour flow	Perinodular	0
	Macrocalcification	1		Peri / intranodular	1
	Peripheral/rim calcification	2	Intranodular	2	
	Punctate echogenic foci	3	TMS classification based on the total score	(negligible or no risk)	TMS < 3
	TR 1 (benign)	0		(low risk)	TMS = 3
TR 2 (not suspicious)	2	(medium or high risk)		TMS > 3	
TIRADS classification based on the total score	TR 3 (mildly suspicious)	3			
	TR 4 (moderately suspicious)	4-6			
	TR 5 (highly suspicious)	>7			

RESULTS

229 thyroid nodules were analysed from 150 patients. Six nodules were excluded due to their purely cystic nature. 38 nodules (17%) were confirmed to be malignant on histopathology. The majority of patients were in their 50's (30.9%) and 60's (23.3%). The median age was 55. There were more females (79.8%) than males (Table II).

The most frequent ultrasound characteristics based on the ACR-TIRADS were iso or hyperechoic (non-hypoechoic) (70.4%), solid or almost completely solid (81.6%), wider than taller (79.8%), smooth or ill-defined margin (82.5%) and none or comet-tail artefact (70.9%). When classified into TR1 to TR5, the majority of our patients fall into category TR 3 and TR 4, 32.7% and 39.9% respectively (Table IV).

Whereas the most frequent characteristics of nodules on ultrasound according to the TMS were the multiple numbers of nodules (75.8%), solid (86.5%); anechoic, isoechoic to hyperechoic (non-hypoechoic) (69.1%), continuous halo (61.4%), macrocalcification (96.4%), regular margin (78.5%) and perinodular Doppler colour flow (74.9%) (Table III). Patients with TMS <3, =3, and >3 comprised of 54.7%, 15.2%, and 30% of the group, respectively (Table IV).

The ultrasound characteristics from both scoring systems were compared with final cytology or histology using simple logistic regression. It was noted that the median ACR-TIRADS and TMS score between benign and malignant nodule was statistically significant (Table

III). In the ACR-TIRADS scoring system, echogenicity and shape of nodules showed a significant difference when comparing benign and malignant nodules.

Table II: Demographics of patients with thyroid nodules and their cytology or histology

Variables	Characteristic	Benign n (%)	Malignant n (%)	p-value
Age Group (years)	< 30	18 (9.7)	5 (13.2)	
	30 – 39	24 (13.0)	9 (23.7)	0.639
	40 – 49	12 (6.5)	2 (5.3)	0.577
	50 – 59	60 (32.4)	9 (23.7)	0.320
	60 – 69	44 (23.8)	8 (21.1)	0.505
	> 70	27 (14.6)	5 (13.2)	0.563
Age (years)	Median Age	55	53	0.153
Sex	Female	154 (83.2)	24 (63.2)	< 0.001
	Male	31 (16.8)	14 (36.8)	
Cytology	Bethesda I	2 (2.0)		
	Bethesda II	71 (70.3)		
	Bethesda III	6 (5.9)		
	Bethesda IV	7 (6.9)		
	Bethesda V	9 (8.9)		
	Bethesda VI	6 (5.9)		
Histology		185 (83.0)	38 (17.0)	

However, when a forward stepwise logistic regression analysis was conducted, hypoechogenicity was the only independent predictor of malignancy. None of the benign nodules exhibited punctate echogenic foci and extrathyroidal extension. Both were exclusively seen in the malignant nodule. This model explains 32.5% of the variability of the histopathology results.

In the TMS score, the number of nodule, echogenicity, margin and Doppler colour pattern showed a significant difference in differentiating benign and malignant nodules (Table III). When forward stepwise logistic regression analysis was performed, single nodule, hypoechogenicity, irregular margin and peripheral/intranodular Doppler flow, indicated strong independent predictors for malignancy. This model explains 54.3% of the variability of the histopathology results ($p < 0.05$).

In the subcategories of ACR-TIRADS, malignancy risk of TR 3, TR 4, and TR 5 were 1.37%, 22.47% and 48.57% respectively, as opposed to nil in categories TR1 and TR2 (Table IV). When grouped into TR <4 and TR

≥ 4 , it was noted that TR ≥ 4 was statistically significant in predicting a malignant thyroid nodule. TR ≥ 4 had approximately 97.37% sensitivity, 52.97% specificity, PPV of 29.84% and NPV of 98.99% (Table IV).

The malignancy risk of TMS category <3, =3 and > 3 were 4.92%, 5.88% and 44.78% respectively. TMS > 3 was statistically significant in predicting a malignant nodule. When comparing TMS results and malignancy, we found that TMS 3 or more had approximately 84.21% sensitivity, 62.70% specificity, PPV of 31.68% and NPV of 95.08% (Table IV).

When using continuous data, diagnostic accuracy of TMS was similar to ACR-TIRADS, with an area under the ROC curve of 0.854 (95% CI, 0.769 to 0.939, $p < 0.001$) and 0.824 (95% CI, 0.765 to 0.883, $p < 0.001$) (Figure 1 & Table IV).

DISCUSSION

With the common use of ultrasound, there has been an increase in the prevalence of thyroid nodules even in asymptomatic patients.¹ Several studies have been carried out to identify certain ultrasound characteristics to differentiate between malignant and benign nodules. However, no one characteristic can be shown to be an absolute indicator of malignancy.¹³ Instead, the combination of ultrasound features predictably correlates more closely with the risk of malignancy.^{14,15,16}

Studies have recognised several characteristics that are associated with malignancy. Taking a similar approach to the well-known breast image reporting and data system (BIRADS), thyroid imaging has been appropriately named TIRADS.^{8,9,14} There are many versions of the TIRADS, with the most recent one being introduced by the American College of Radiology as ACR-TIRADS in 2017.¹²

In 2009, Horvath et al. proposed the use of TIRADS classification to classify ultrasound features and identify nodules that will undergo FNAC.⁹ This was followed by a study by Park et al. with a similar aim. Both of them proposed 10 and 12 ultrasound features respectively.¹⁸ However due to its complexity, it was not widely accepted in clinical practice. These models were then

Table III: Association of TIRADS and TMS characteristics with malignancy on histopathology.

TIRADS					TMS				
Variables	Characteristics	Benign n (%)	Malignant n (%)	p-value	Variables	Characteristic	Benign n(%)	Malignant n(%)	p-value
TIRADS score	Median score	2	5	<0.001	TMS	Median score	2	6	< 0.001
Echogenicity	Non-hypoechoic	143 (77.3)	14 (36.8)	< 0.001	Number	Multiple	155 (83.8)	14 (36.8)	< 0.001
	Hypoechoic	42 (22.7)	24 (63.2)			Single	30 (16.2)	24 (63.2)	
Composition	Spongiform or cystic	15 (8.1)	2 (5.3)	0.943	Structure	Colloidal	29 (15.7)	1 (2.6)	0.062
	Mixed solid cystic	21 (11.4)	3(7.9)			Solid	156 (84.3)	37 (97.4)	
	Solid / almost solid	149 (80.5)	33 (86.8)			0.514			
Shape	Wider than tall	156 (84.3)	22 (57.9)	<0.001	Echogenicity	Non-hypoechoic	144 (77.8)	10 (26.3)	< 0.001
	Taller than wide	29 (15.7)	16 (42.1)			Hypoechoic	41 (22.2)	28 (73.7)	
Margin	Smooth or ill defined	161 (87)	23 (60.5)	N/A	Halo	Continuous	91 (61.1)	22 (57.9)	0.623
	Lobulated or irregular	24 (13)	12 (31.6)			Discontinuous	58 (38.9)	16 (42.1)	
	Extrathyroidal extension	0 (0)	3 (7.9)		Calcification	Macro	185 (100.0)	30 (78.9)	N/A
Echogenic foci	None or comet tail	131 (70.8)	27 (71.1)	N/A		Micro	0 (0.0)	8 (21.1)	
	Macrocalcification	50 (27)	7 (18.4)		Margin	Regular	159 (85.9)	16 (42.1)	< 0.001
	Peripheral calcification	4 (2.2)	2 (5.3)			Irregular	26 (14.1)	22 (57.9)	
	Punctate echogenic foci	0 (0)	2 (5.3)		Colour flow	Perinodular	150 (81.1)	17 (44.7)	< 0.001
					Peri/intranodular	21 (11.4)	13 (34.2)		
						Intranodular	14 (7.6)	8 (21.1)	< 0.001

taken as a guide by the American College of Radiology, and in 2017 they developed the ACR-TIRADS.

In 2013, Pompili et al proposed the TMS score which classified a thyroid nodule into three risk categories:- no risk or negligible risk (TMS<3), low risk (TMS = 3) and medium or high risk (TMS>3).¹¹ Another well-known thyroid ultrasound classification by the American Thyroid Association (ATA) in 2015, introduced high, intermediate, low and very low suspicious sonographic patterns. Each of these features carries a malignancy risk of 70-90%, 10-20%, 5-10% and less than 3% respectively.¹⁷

It recommends fine-needle aspiration biopsy (FNAB) for nodules depending on the features and size of the nodule.¹⁷ In general, nodules <1 cm are not recommended for biopsy. Distinct from the ATA, both the ACR-TIRADS and TMS allocate scores to the ultrasound features and classified them with their own

risk of malignancy.

In this study, ultrasound features were assessed and individual features scores were summed to obtain ACR-TIRADS and TMS scores for the nodule according to Table I. The sum of ACR-TIRADS scores ranged from 0 to 14, whereas TMS scores ranged from 0 to 11. Both scores were compared with the definitive cytologic or histologic diagnosis.

In a multicentre analysis of thyroid nodule, there was a stepwise increase in the risk of malignancy for each point awarded by ACR TI-RADS. The published rate was; TR1: 0.3%, TR2: 1.5%, TR3: 4.8%, TR4: 9.1%, TR5: 35%.¹⁹ In this study, however, malignancy risk for TR1 & 2 were nil. TR3 had a risk of 1.37%, TR4 22.47% and TR5 48.57%. Due to its higher risk of malignancy in TR4 and TR5, we divided the classification into two, namely TR<4 and TR≥4. Overall, TR≥4 category had a sensitivity of 97.37%, specificity of 52.97%, positive predictive value (PPV) of

TABLE IV: TMS and TIRADS scores and their risk of malignancy, sensitivity, specificity, PPV, NPV and accuracy.

US system	US Score	Malignant n(%)	Malignancy risk (%)	Grouped TIRADS	Benign n(%)	Malignant n(%)	p-value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
TI-RADS	TR 1 (n=4)	0 (0)	0.0	TR <4 (n=99)	98 (53.0)	1 (2.6)	<0.001	97.37	52.97	29.84	98.99	60.54
	TR 2 (n=22)	0 (0)	0.0									
	TR 3 (n=73)	1 (0.14)	1.37									
	TR 4 (n=89)	20 (22.5)	22.47	TR ≥4 (n=134)	87 (47.0)	37 (97.4)						
	TR 5 (n=35)	17 (48.6)	48.57									
(82.4 - continuous data)												

US system	US Score	Malignant nodules n (%)	Malignancy risk (%)	p-value	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
TMS	TMS<3 (n=122)	6 (15.8)	4.92	0.822	84.21	62.70	31.68	95.08	66.37
	TMS=3 (n=34)	2 (5.3)	5.88						
	TMS>3 (n=67)	30 (78.9)	44.78	< 0.001					
(85.4 - continuous data)									

US = Ultrasound, TMS = Total Malignancy Score, TIRADS = Thyroid Image Reporting and Data System, PPV = Positive predictive value, NPV = Negative predictive value.

29.84% and negative predictive value (NPV) of 98.99% (Table IV). These findings were similar to that reported by Xu et al, which showed the sensitivity of 96.6%, specificity of 52.9% and NPV of 95.8%, however, the PPV was significantly higher in their study at 58.6%.²⁰

Both the TMS and the ACR-TIRADS system showed that hypoechoic nodule was more likely to be a malignant nodule. This finding has been similarly shown in several other studies.^{8,9,10} However, Anil et al. in 2011 showed that although specificity was high, the sensitivity for this feature was low. Therefore, the finding of a hypoechoic nodule alone may not be sufficient to suggest malignancy.²⁹

Pompili et al. found that hypoechogenicity, solid structure, irregular margins and the number of nodules as predictors of malignancy in TMS classification.²¹ Similarly in this study apart from hypoechoic features in the nodule, patients with single, irregular margins, peripheral and intranodular Doppler flow were more likely to be malignant. However, the solid or colloid structure of a nodule did not show a significant difference in detecting malignancy. The malignancy risk for TMS <3, =3 and >3 were 4.92%, 5.88% and 44.78% respectively (Table IV). These malignancy risks were lower than the ones reported by Pompili et al in

2013.¹¹ The overall sensitivity of TMS categories ≥3 was 84.21%, however, the specificity was 62.70% which is higher than that of ACR-TIRADS. Even the PPV of this study was higher as compared to the ACR-TIRADS at 31.68%.

Puno-Ramos et al., in their study, showed that a nodule was 11.3 times more likely to be malignant with the presence of microcalcification. It was also noted that two or more features predictive of malignancy had a higher likelihood to be malignant on cytopathology.²² On the other hand, Smith-Bindman et al., concluded that three nodule characteristics namely microcalcification, size greater than 2 cm and an entirely solid composition were statistically significant in predicting thyroid malignancy.²³ Remonti et al. in their meta-analysis, revealed multiple characteristics, namely solid nodule, hypoechogenicity, irregular margins, absence of halo, microcalcifications, central vascularisation, solitary nodule, heterogeneity, taller than wide shape and elasticity, all significantly associated with malignancy with an odds ratio (OR) ranging from 1.77 to 35.7. However, ultrasound has only 26.7-63% sensitivity in predicting malignancy. Thus, they concluded that no single feature is independently reliable as a guide to decide on FNAC.¹³

Fine needle aspiration cytology has reported sensitivity between 65-98% and specificity between 73-100%.^{24,25} Approximately 3-7% of biopsied thyroid nodule are malignant. This was similar in our study, where the confirmed malignant nodule on FNAC was 5.9%. The malignancy rate for Bethesda I in published studies ranged between 1-17%.²⁶ In our study, 2.0% of the biopsied patients were classified under Bethesda I, of which all were benign on histopathology (Table II). Thus, ultrasound assessment must be used to differentiate benign from malignant to decrease unnecessary biopsy. However, there was a limitation to this, as the number of patients with Bethesda 1 who underwent surgery was small.

Overall, both systems showed good diagnostic accuracy with ACR-TIRADS and TMS showing area under the curve of 0.824 and 0.854 respectively (Figure 1). Both results are comparable with studies done by Xu et al and Pompili et al.^{20,21} This is a good yield and proves that both these systems are an effective tool for selecting patients that require FNAC. However, it should be stressed that this should be complemented with FNAC as ultrasound is only a screening tool to identify high-risk nodules.

The unique feature of both the ACR- TIRADS and TMS, when compared to other thyroid ultrasound classifications, is the ability, to sum up, the total scores of all features and classify nodules into risk-stratified groups, making it clear and easy to use and apply. Application of both these systems can potentially provide cost-saving measures to the healthcare system, achieved by a reduction in the number of unnecessary FNAC. Medical personnel managing patients with thyroid nodule must understand the rationale of using and applying either one of these scores. Also, the appropriate personnel should be trained and competent in performing thyroid US as well as able to carry out FNAC whenever necessary. From our study, we recommend that FNAC be carried out for ACR-TIRADS ≥ 4 and TMS ≥ 3 . Both these systems are applicable in our setting as both of them show good diagnostic accuracy. Thus, we leave it to the discretion of the attending physician to decide on which scoring system they prefer.

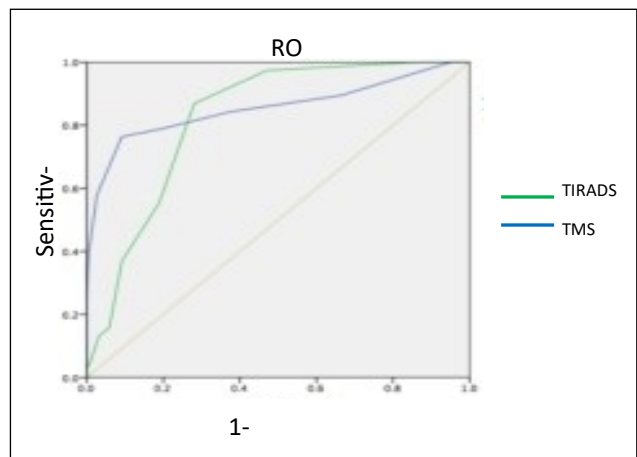


Figure 1: Receiver Operating Characteristic (ROC) curve comparing the accuracy of ACR-TIRADS and TMS

STUDY LIMITATION

This was a cross-sectional study hence there might be selection bias. Approximately 70.4% of our subjects underwent surgery due to the presence of ultrasound features suggestive of malignancy. Consequently, our malignancy rate is higher at 17.04% as compared to an FNAC based series wherein the malignancy rate is only 3 to 7%.²⁴ Secondly, 71 nodules with Bethesda II were considered to be definitively benign, and no further procedures or follow-up was performed. However, this reflects clinical practice but at the expense of a possibility of the presence of false negatives among the cytology results. Moreover, it was unethical to subject patients to undergo surgery for a nodule that is highly likely to be benign for the sole purpose of obtaining histological proof. Our study population is from a single institution which might not be reflective of the entire population. To overcome this, a prospective multicentre study would be more representative.

CONCLUSION

In conclusion, both the ACR-TIRADS and TMS scoring system is useful in diagnosing thyroid nodules for malignancy. It allows for the selection of nodules with a high risk of malignancy to be subjected to FNAC, avoiding unnecessary procedures. These scores are simple, easily reproducible and reliable. TMS is comparable and not inferior to ACR-TIRADS. The latter is more practical for use as growth and Doppler characteristic is not included in the assessment. Nonetheless, either of these systems when used in an

institution delivers uniform understanding and will help radiologists and surgeons in providing standardized treatment for patients.

ACKNOWLEDGEMENT

The authors wish to thank the Head of Department, lecturers, trainees, staff and everyone else who were either directly or indirectly involved in supporting this study throughout its course.

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