Comparison between sonographic features using thyroid imaging reporting and data systems criteria and fine needle aspiration cytology in the diagnosis of solitary and dominant thyroid nodule

Original Article

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ABSTRACT

Background: The accuracy of both the Thyroid Imaging Reporting and Data Systems (TIRADS) staging system and fine needle aspiration cytology (FNAC) for the diagnosis of malignant thyroid nodules remains controversial.

Objective: This study aimed to compare the utility of sonographic features using TIRADS criteria versus FNAC in the diagnosis of solitary and dominant thyroid nodules.

Patients and Methods: This cross-sectional study enrolled patients with solitary or dominant thyroid nodules of both sexes. Patient data were obtained from their medical records. Thyroid ultrasound characteristics, FNAC, and cell block slides were reviewed. The TIRADs approach and the Bethesda system were used to categorize thyroid lesions. The receiver operating characteristic curve was performed on all radiological and pathological findings.

Results: The study included 158 patients with solitary or dominant thyroid nodules. TIRADS was significantly associated with Bethesda diagnoses and the histopathological diagnosis of malignant thyroid nodules (*P<0.001*). At a cutoff of greater than or equal to 3, the TIRADS showed significantly good discrimination between malignant and benign nodules (area under the curve=0.842, *P<0.001*). At a cutoff greater than or equal to II, Bethesda showed a significant fair power of diagnosis of malignant nodules (area under the curve=0.784, *P<0.001*). The overall accuracy of Bethesda was slightly higher compared with TIRADS. There was a significantly poor concordance between TIRADS and Bethesda classification systems (weighted kappa=0.186, 95% confidence interval: 0.117–0.255, *P<0.001*).

Conclusion: In patients with solitary and dominant thyroid nodules, there is a poor diagnostic correlation between TIRADS and Bethesda classification systems. However, the overall accuracy of Bethesda was slightly higher than that of TIRADS.

Key Words: Bethesda, fine needle aspiration cytology, thyroid nodule, thyroid imaging reporting and data systems.

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INTRODUCTION

Thyroid nodules are common in the community, with an incidence rate of 4– 7% per 10 to 18 million people. They can result from a variety of thyroid problems. These growths are identified as a local proliferation of atypical thyroid cells that are distinctly different from the normal thyroid tissue surrounding the scattered mass[1]. The majority of nodules identified are non-malignant, although there has been a reported increase in the incidence of thyroid cancer[2].

The distinction between benign and malignant thyroid nodules is of great clinical importance. A four-step process is required to diagnose thyroid nodules. This method begins with a thorough assessment of the patient's medical history and clinical evaluation. This is followed by a thyroid function test, thyroid ultrasound, and finally ultrasound-guided aspiration cytology[3]. The rate of detection of thyroid nodules by cervical palpation is ~5%[4], but the rate of incidental detection of nodules by ultrasound shows a prevalence ranging from 20 to 76%[5].

Ultrasonography plays a pivotal role in the clinical assessment of nodular thyroid lesions, representing a crucial aspect of thyroid imaging. However, the nature of thyroid nodules is complex, and the ultrasound characteristics of benign and malignant nodules are often similar, which presents a challenge for accurate diagnosis. Consequently, the accuracy of the diagnosis hinges significantly on the clinical expertise of the sonographer. To guarantee consistent and objective assessment of the nature of thyroid nodules, it is imperative to establish a standardized classification and grading system for their severity. This will facilitate consistent evaluation and classification of thyroid nodules by physicians, irrespective of the hospital or physician involved[6].

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The thyroid imaging reporting and data systems (TIRADS) is a classification system that employs ultrasound features to enhance the selection of thyroid nodules for fine needle aspiration cytology (FNAC)[7]. TIRADS are distinguished by a set of defining characteristics and a spectrum of potential risks associated with malignancy[8]. Nevertheless, there is a dearth of definitive indicators that can unambiguously differentiate between benign and malignant lesions[9].

FNAC is a pivotal diagnostic technique for thyroid nodules, offering a safe, cost-effective, and reliable means of distinguishing between benign and malignant lesions[10]. The Bethesda method was developed to create a standardized reporting system for thyroid FNAC, with the aim of facilitating efficient communication between pathologists, doctors, and radiologists[11]. The Bethesda system has defined six categories, each associated with a distinct level of malignancy risk and requiring specific clinical care[12]. The recommended clinical therapy for cases classified under the Bethesda system varies depending on the category. For category II, it is recommended that clinical and sonographic follow-up be conducted. In cases where the diagnosis falls within categories V or VI, the recommended surgical procedure is a near-total thyroidectomy or lobectomy[11].

The question of whether thyroid nodules are benign or malignant and which patients should undergo FNAC remains a topic of contention in the medical management of thyroid nodules. This study aimed to compare the diagnostic utility of sonographic features using TIRADS criteria with that of FNAC in the diagnosis of solitary and dominant thyroid nodules.

PATIENTS AND METHODS:

Ethical considerations

Following approval by the research ethics committee of the Faculty of Medicine, Cairo University, Egypt. The relevant medical records were obtained, and the confidentiality of each participant's information was guaranteed.

Study design, setting, and location

This cross–sectional study was conducted at the Interventional Radiology Unit, Radiology Department, Cairo University Hospital, Egypt, between April and December 2021. The investigators obtained the requisite information from the medical records.

Study patients

The study included data from patients of both sexes and of all ages with euthyroid solitary or dominant nodules. Subsequently, the patients underwent ultrasound evaluation, followed by FNAC and surgical excision of the nodule. Patients exhibiting abnormal bleeding profiles, nodules measuring less than 1 cm, or nodules comprising entirely cystic components were excluded from the study. Additionally, patients who did not undergo further FNAC or surgery following FNAC were excluded.

Study procedures

The clinical data of the patients, including their age, sex, and clinical presentation, were obtained from their reports. A radiological evaluation was conducted on all cases, and FNAC was performed with the guidance of ultrasound.

Conventional ultrasound

Patients were placed in a supine position with their necks slightly extended. The B-mode ultrasonography was performed on all nodules using the Canon Xario 200 machine (Canon Medical Systems Corporation, Tustin, California, United States) to identify and analyze the number, size, echogenicity, shape, border, and composition of the nodules. Calcification was also identified.

The TRIADS technique has been used to classify thyroid lesions into five different categories. The radiological characteristics of the thyroid nodule include its composition, echogenicity, shape in the transverse plane, borders, and the presence of echogenic foci with identified calcifications[8]. TIRADS scores of 4 and 5 were classified as indicative of malignancy, while scores of 1-3 were classified as not indicative of malignancy.

Ultrasound-guided FNAC

A comprehensive review of the patient's bleeding profile and complete blood count was conducted, revealing an acceptable international normalized ratio (INR) of up to 1.3 and a platelet count exceeding 150 000 cells/ml. Subsequently, ultrasound-guided FNAC was performed on the cases. Suspicious nodules (TIRADS 3, 4, 5) were subjected to aspiration to confirm or exclude the presence of malignancy. Nodules exhibiting benign characteristics (TIRADS 1, 2) were only aspirated if they exceeded a diameter of 1 cm. While the TIRADS guidelines do not recommend FNAC in categories 1 and 2, they are consistent with most other guidelines in recommending FNA for highly suspicious nodules measuring 1 cm or larger. In addition, FNA is recommended for subcentimeter nodules that are suspicious for malignancy. This includes nodules with clinical or imaging abnormal lymph nodes. It also includes nodules in patients with a significant history of malignancy. However, practical aspiration and handling of sub-centimeter nodules is difficult. Therefore, nodule size was considered in this study[8,11,13,14].

All aspirations were conducted under ultrasound guidance with the use of a 10-gauge needle, without the administration of local anesthetic. A minimum of five slides were obtained for cytologic examination. The slides were immersed in 95% alcohol and conveyed to the pathology department of the hospital for examination using the most recent iteration of the Bethesda system, 2017. To ensure consistency in interpretation, the same examiner conducted both the ultrasound guidance examination and the ultrasound guidance-guided FNAC procedure.

The thyroid lesions were classified in accordance with the six categories of the Bethesda system. The categories are as follows: The categories are as follows: Bethesda I, which is nondiagnostic; Bethesda II, which is benign; Bethesda III, which is atypia of undetermined significance or follicular lesion of undetermined significance; Bethesda IV, which is follicular neoplasm or suspicious for follicular neoplasm; Bethesda V, which is suspicious for malignancy; and Bethesda VI, which is malignant. A thyroid fine needle aspiration (FNA) sample is deemed suitable for testing if it contains a minimum of six clusters of benign follicular cells, with each cluster comprising a minimum of 10 cells[12]. If smears contained atypical cells, they were always deemed sufficient, irrespective of the number of cells present.

Statistical analysis

Data were tabulated and analyzed by the statistical package for the social sciences software program, IBM SPSS Statistics for Windows, version 27 (IBM Corp., Armonk, New York, USA). Categorical data were presented as numbers and percentages while numerical data were initially verified for normality using the Shapiro-Wilk test and were expressed as the mean±standard deviation as they were normally distributed. Furthermore, receiver operating characteristics (ROC) curve analysis was applied to determine the best cutoff and the discrimination power of TIRADS and Bethesda scoring systems for diagnosing malignant thyroid nodules considering histopathologic diagnosis after surgery as the gold standard. Then, the associations of TIRADS and Bethesda with histopathologic diagnosis of malignant thyroid nodules were performed by Pearson's χ^2 test, and the diagnostic accuracy indices of each classification system were calculated. They included sensitivity, specificity, positive predictive value, negative predictive value, and positive and negative likelihood ratios with their 95% confidence intervals. Finally, concordance between TIRADS and Bethesda classification systems was done by Cohen's weighted kappa statistics. *P value* less than 0.05 was considered statistically significant.

RESULTS:

This study included 158 patients with solitary or dominant thyroid nodules. Females outnumbered males (68.4% vs. 31.6%, respectively), and their ages ranged between 14 and 72 years, with a mean age of 41.2±13.2 years. Dominant nodules (99, 62.7%) were more frequent than single ones (59, 37.3%). The nodules were distributed mainly in the right (72, 45.6%) and left (66, 41.8%) lobes, and less frequently in the isthmus (5, 3.2%). The composition of the nodules was either solid (63, 39.9%), cystic (18, 11.4%), or mixed solid and cystic (77, 48.7%). The nodules' echogenicity varied between isoechoic (70, 44.3%), hypoechoic (69, 43.7%), and less frequently hyperechoic (19, 12.0%). The shape of the nodules was commonly wider than taller (123, 77.8%), and their margins were typically smooth (108, 68.4%). Microcalcification was detected in 41 (25.9%), while only 13 (8.2%) showed macrocalcification. TIRADS scoring for all patients included TIRADS 1 (2, 1.3%), TIRADS 2 (18, 11.4%), TIRADS 3 (71, 44.9%), TIRADS 4 (40, 25.3%), TIRADS 5 (27, 17.1%). Bethesda classification of the FNAC of the nodules revealed Bethesda I in 31 (19.6%), Bethesda II in 76 (48.1%), Bethesda III in 26 (16.5%), Bethesda IV in 16 (10.1%), and Bethesda V in nine (5.7%) patients. After surgical removal of all nodules, histopathology diagnosis confirmed malignant thyroid nodules in 53 (33.5%) patients (Table 1).

The percentage of a benign FNAC (Bethesda Class II) in TIRADS categories 1 and 2 was 100 and 61.1%, respectively, while it was 62, 45, and 3.7%, respectively, for TIRADS 3, 4, and 5 classes. Further, the percentage of a suspicious malignancy FNAC (Bethesda Class V) in TIRADS 4 and 5 classes was 5 and 25.9%, respectively, however, it was not detected in TIRADS 1, 2, and 3 (0.0%). The percentage of a malignant thyroid nodule diagnosis after surgical removal was 16.9, 37.5, and 96.3% in TIRADS 3, 4, and 5 classes, respectively. The pathology diagnosis was Hashimoto thyroiditis (100%) in TIRADS 1 class and colloid goiter in 12 out of 18 (66.7%) cases in TIRADS class 2. Regarding TIRADS 3 class, colloid and adenomatous goiters were the most frequent diagnoses (43.7 and 11.3%, respectively). The class TIRADS 4 included benign pathologies such as Hashimoto thyroiditis (7, 17.5%) and adenomatous goiter (6, 15%) as well as malignant ones such as papillary thyroid carcinoma (8, 20%) and Hurthle cell neoplasm (3, 7.5%). In TIRADS class 5, 26 out of 27 cases attained malignant diagnosis, which was papillary thyroid carcinoma in more than half of cases (14, 51.9%) as shown in (Table 2).

ROC curve analysis revealed that the TIRADS classification system at a cutoff of more than 3 showed significantly good discrimination between malignant and benign nodules (AUC=0.842, *P<0.001*). Alternatively, the diagnostic performance of the Bethesda system was nonsignificantly lower than the TIRADS. At a cutoff more than II, Bethesda showed a significant fair power of diagnosis of malignant nodules (AUC=0.784, **P<0.001**) (Table 3 and Fig. 1).

Table 4 demonstrates significant associations between TIRADS and Bethesda diagnoses and the histopathology diagnosis of malignant thyroid nodules (*P<0.001*). Out of 53 malignant thyroid nodules, TIRADS classes of more than 3 were able to diagnose 41 (77.4%) while Bethesda classes of more than II diagnosed 37 (69.8%).

The TIRADS showed a higher true positive rate and sensitivity (77.4 and 77.0%, respectively,) compared with Bethesda (69.8 and 70.0%, respectively), whereas the true negative rate and specificity were higher in Bethesda (86.7 and 87.0%, respectively), than TIRADS (75.2 and 75%, respectively). Bethesda system showed a high positive predictive value (84.34%) while TIRADS showed a high negative predictive value (76.53%). Bethesda's overall accuracy (78.5%) was slightly higher compared with TIRADS (76.0%) as shown in (Table 5).

Table 6 shows a significant poor concordance between TIRADS and Bethesda classification systems (weighted kappa=0.186, 95% CI: 0.117–0.255, *P<0.001*).

Table 1: Baseline patient characteristics and nodules (N=158)

Variable	*N* (%)
Age, years	
Range	14.0–72.0
Mean±SD	41.2±13.2
Sex	
Female	108 (68.4)
Male	50 (31.6)
Type of nodules	
Dominant	99 (62.7)
Single	59 (37.3)
Site of nodule	
Right lobe	72 (45.6)
Left lobe	66 (41.8)
Bilateral	15 (9.5)
Isthmus	5 (3.2)
Composition	
Solid	63 (39.9)
Cystic	18 (11.4)
Mixed cystic and solid	77 (48.7)
Echogenicity	
Isoechoic	70 (44.3)
Hypoechoic	69 (43.7)
Hyperechoic	19 (12.0)
Shape	
Taller than wider	35 (22.2)
Wider than taller	123 (77.8)
Margin	
Smooth	108 (68.4)
Ill defined	38 (24.1)
Irregular	12 (7.6)
Calcifications	
None	104 (65.8)
Microcalcification	41 (25.9)
Macrocalcification	13 (8.2)
TIRADS	
1	2 (1.3)
2	18 (11.4)
3	71 (44.9)
4	40 (25.3)
5	27 (17.1)
Bethesda	
1	31 (19.6)
2	76 (48.1)
3	26 (16.5)
4	16 (10.1)
5	9 (5.7)
Histopathology	
Benign	105 (66.5)
Malignant	53 (33.5)

Table 2: Distribution of TIRADS, Bethesda, and pathology results of the studied patients

TIRADS	*N* (%)	Bethesda	*N* (%)	Type	*N* (%)	Pathology	*N* (%)
1	2 (1.3)	II	2 (100)	Benign	2 (100)	Hashimoto thyroiditis	2 (100)
				Malignant	0	None	0
2	18 (11.4)	I	6 (33.3)	Benign	18 (100)	Colloid goiter	12 (66.7)
				Malignant	0	Hashimoto thyroiditis	2 (11.1)
		II	11 (61.1)			Adenomatous goiter	2 (11.1)
						Toxic goiter	1 (5.6)
		III	1 (5.6)			Thyroiditis	1 (5.6)
3	71 (44.9)	I	14 (19.7)	Benign	59 (83.1)	Colloid goiter	31 (43.7)
				Malignant	12 (16.9)	Adenomatous goiter	8 (11.3)

		II	44 (62)			Hyperplastic nodule	7 (9.9)
						Hashimoto thyroiditis	5 (7.0)
		III	10 (14.1)			Papillary thyroid carcinoma	4 (5.6)
						Hurthle cell neoplasm	4 (5.6)
		IV	3 (4.2)			Follicular adenoma	4 (5.6)
						Toxic goiter	2 (2.8)
						Follicular carcinoma	2 (2.8)
						Chronic lymphocytic thyroiditis	2 (2.8)
						Papillary Microcarcinoma	1 (1.4)
						Medullary thyroid carcinoma	1 (1.4)
4	40 (25.3)	I	8 (20)	Benign	25 (62.5)	Hashimoto thyroiditis	8 (20)
				Malignant	15 (37.5)	Papillary thyroid carcinoma	7 (17.5)
		II	18 (45)			Adenomatous goiter	6 (15)
						Colloid goiter	5 (12.5)
		III	8 (20)			Follicular adenoma	4 (10)
						Hurthle cell neoplasm	3 (7.5)
		IV	4 (10)			Papillary microcarcinoma	2 (5)
						Thyroiditis	1 (2.5)
		V	2 (5)			Microinvasive follicular carcinoma	1 (2.5)
						Follicular variant of papillary thyroid carcinoma	1 (2.5)
						Follicular carcinoma	1 (2.5)
						Chronic lymphocytic thyroiditis	1 (2.5)
5	17 (17.1)	I	3 (11.1)	Benign	1 (3.7)	Papillary thyroid carcinoma	14 (51.9)
				Malignant	26 (96.3)	Medullary thyroid carcinoma	4 (14.8)
		II	1 (3.7)			Follicular carcinoma	4 (14.8)
						Papillary microcarcinoma	3 (11.1)
		III	7 (25.9)			Hurthle cell neoplasm	1 (3.7)
						Colloid goiter	1 (3.7)
		IV	9 (33.3)				
		V	7 (25.9)				

N, number; TIRADS, thyroid imaging reporting and data systems.

Table 3: Receiver operating characteristics curve analysis for assessing diagnostic performance of TIRADS and Bethesda for malignant thyroid nodules

Best cutoff	AUC	95% CI (AUC)	*P* value
TIRADS >3	0.842	0.775–0.895	<0.001*
Bethesda >II	0.784	0.711–0.845	<0.001*

A pairwise comparison between both curves revealed nonsignificant difference (*P=0.228*).
AUC, area under the curve; CI, confidence interval; TIRADS, thyroid imaging reporting, and data systems.

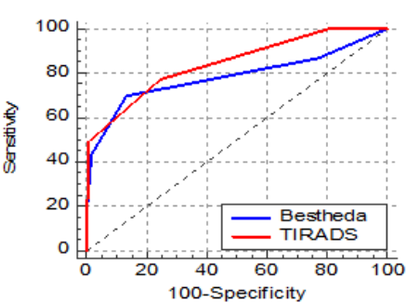

Fig. 1: Receiver operating characteristics curves of TIRADS and Bethesda for diagnosing malignant thyroid nodules. TIRADS: thyroid imaging reporting and data systems.

Table 4: Associations of TIRADS and Bethesda with histopathologic diagnosis of malignant thyroid nodule

	Histopathology			
	Benign (*N*=105) *n* (%)	Malignant (*N*=53) *n* (%)	Total (*N*=158) *n* (%)	*P* value
TIRADS >3				
Benign	79 (75.2)	12 (22.6)	91 (57.6)	<0.001*
Malignant	26 (24.8)	41 (77.4)	67 (42.4)	
Bethesda >II				
Benign	91 (86.7)	16 (30.2)	107 (67.7)	<0.001*
Malignant	14 (13.3)	37 (69.8)	51 (32.3)	

N, number; TIRADS, thyroid imaging reporting and data systems.
*Significant at *P* less than 0.05.

Table 5: Diagnostic accuracy of TIRADS and Bethesda compared with histopathologic diagnosis of malignant thyroid nodule

	TIRADS	Bethesda
True positive	77.4	69.8
False negative	22.6	30.2
True negative	75.2	86.7
False positive	24.8	13.3
Sensitivity (95% CI)	77.0 (67.5–84.8)	70.0 (60.0–78.8)
Specificity (95% CI)	75.0 (65.3–83.1)	87.0 (78.8–92.9)
Positive predictive value (95% CI)	75.5 (68.3–81.4)	84.34 (76.1–90.0)
Negative predictive value (95% CI)	76.53 (69.1–82.6)	74.4 (68.0–79.8)
Positive Likelihood Ratio (95% CI)	3.08 (2.16–4.40)	5.38 (3.19–9.08)
Negative Likelihood Ratio (95% CI)	0.31 (0.21–0.45)	0.34 (0.25–0.47)
Accuracy (95% CI)	76.0 (69.4–81.7)	78.5 (72.2–83.9)

CI, confidence interval; TIRADS, thyroid imaging reporting and data systems.

Table 6: Concordance between TIRADS and Bethesda classification systems

	Bethesda, *N* (%)					
TIRADS	I	II	III	IV	V	
1	0	2	0	0	0	2 (1.3)
2	6	11	1	0	0	18 (11.4)
3	14	44	10	3	0	71 (44.9)
4	8	18	8	4	2	40 (25.3)
5	3	1	7	9	7	27 (17.1)
	31 (19.6)	76 (48.1)	26 (16.5)	16 (10.1)	9 (5.7)	158 (100)
Weighted kappa=**0.186 (95% CI: 0.117–0.255)**						
P* value <0.001						

CI, confidence interval; N, number; TIRADS, thyroid imaging reporting and data systems.
*Significant at *P* less than 0.05.

DISCUSSION

A thyroid ultrasound is a common initial evaluation procedure for the thyroid gland[15,16]. FNAC is an inexpensive and effective method of identifying thyroid cancer; however, it does entail a surgical procedure. The question of which patients with thyroid nodules should undergo FNAC and the differentiation between benign and malignant nodules remains a topic of debate in the field of thyroid nodule care. The objective of this study was to compare the diagnostic value of TIRADS criteria when used alone or in combination with FNAC in the diagnosis of solitary and dominant thyroid nodules.

The objective of the ultrasound examination of thyroid nodules was to ascertain the probability of malignancy in addition to the findings of FNAC. This

would facilitate the selection of the most appropriate course of further treatment. The most common sonographic features of malignant nodules include hardness, lobulation or irregularity of margin, taller than wide forms, peripheral calcifications, and punctate echogenic regions within the nodule[17]. These features have been recognized in numerous studies as potential indicators of malignancy[18–21].

The findings indicated a preponderance of females relative to males, with a mean age of 41.2±13.2 years. The most prevalent category was TIRADS Category III. Similarly, several studies conducted both inside and outside Egypt[22–24] have reported a female predominance for thyroid nodules at different ages and a similar prevalence of TIRADS categories. Moreover, the Bethesda assessment indicated that the Bethesda I category was identified in 19.6% of the patients, a figure that varies considerably in previous investigations, ranging from 1.2 to 35.3%[22,25]. The benign category II was identified in 48.1% of the patients. This category was the most prevalent, with reported percentages ranging from 32.9 to 87.5%[22,26]. The discrepancy can be attributed to technical and interpretive aspects. Following surgical removal of all nodules, malignant thyroid nodules were confirmed in 33.5% of the patients in the study, which was a relatively higher percentage than that reported by Fawzy *et al*. (27.4%)[22]. This discrepancy is contingent upon whether the study was conducted at a tertiary care center, where patients are referred and therefore not a true representation of the overall population, or at a primary care center, which accurately reflects the general population with a significant proportion of malignant cases.

The Bethesda reporting system is a highly utilized tool across the globe. The method is employed by pathologists to facilitate effective communication with physicians, offering a standardized reporting template for thyroid fine-needle aspiration that has been endorsed by the American Thyroid Association[27].

In correlating TIRADS with the Bethesda system for reporting thyroid cytopathology, it was observed that the percentage of suspicious malignancy in TIRADS 4 and 5 classes was 5% and 25.9%, respectively. However, this was not detected in TIRADS 1, 2, and 3. The percentage of malignant thyroid nodule diagnoses following surgical removal was 16.9, 37.5, and 96.3% in the TIRADS 3, 4, and 5 classes, respectively. In a study by Modi *et al*.[28], no association was found between TIRADS 2 or TIRADS 3 nodules and malignant cytopathology. Additionally, only 21.5% of TIRADS 5 nodules were identified as malignant. Moreover, the present findings align with those of numerous prior studies[7,29,30], wherein none of the nodules classified as TIRADS 2 were identified as malignant. This indicates that fine-needle aspiration cytology (FNAC) can be circumvented in patients presenting with TIRADS 2 nodules. These nodules are the most prevalent among newly diagnosed cases, suggesting that avoiding unnecessary biopsies and surgical procedures can spare patients from unwarranted interventions. Contrary, Periakaruppan *et al*.[30] observed that the risk of malignancy for TIRADS 3, TIRADS 4, and TIRADS 5 was 2.2, 38.5, and 77.8%, respectively. In addition, Horvath *et al*.[7] reported that the malignancy rate in cases classified from TIRADS 3 to 5 was 14.1, 45, and 89.6%, respectively. Chaturvedi *et al*.[29] determined that the probability of malignancy was 13.6% for TIRADS 3, 27% for TIRADS 4, and 63.6% for TIRADS 5. In a study by Barbosa *et al*.[19], the incidence of thyroid cancer in patients with TIRADS 3 was found to be 23.3%. De *et al*.[21] observed that TIRADS 3 and TIRADS 4 exhibited malignancy rates of 22 and 29%, respectively. Hussein *et al*.[23] reported a prevalence of 38.5% in TIRADS 5. However, the rates for TIRADS 3 and TIRADS 4 were 14.3 and 22.5%, respectively. A statistically significant trend was observed, indicating an increased risk of malignancy as nodules progressed from TIRADS 3 to TIRADS 5. The discrepancies in these results may be attributed to the challenge of differentiating between calcifications and comet-tail artifacts during sonographic inspection, which directly influences the final score assigned to the nodule. Additionally, the presence of macrocalcifications and hyperechoicity in previous systems did not correlate with the presence of malignancy. Moreover, disparate methodologies were employed for cytological and histopathological diagnosis.

Geographic variation should be considered as a potential factor contributing to the higher malignancy incidence in TIRADS 3 nodules. A meta-analysis conducted by Vuong *et al*.[31] aimed to examine the differences in diagnosis frequency, resection rate, and risk of malignancy between Western (American and European) and Asian cytopathology methods. Compared with the Asian practice, the Western series had a significantly reduced risk of malignancy in most of the Bethesda categories. When examining indeterminate nodules, the risk of malignancy was significantly lower in the Western series than in the Asian series.

A ROC curve analysis revealed that the TIRADS classification system exhibited a notable capacity to differentiate between malignant and benign nodules when a cutoff value of 3 or above was employed. At a cutoff value of greater than II, the Bethesda system demonstrated a notable capacity for accurately diagnosing malignant nodules. The TIRADS demonstrated superior performance in terms of true positive rate and sensitivity compared with the

Bethesda system. Conversely, the true negative rate and specificity were more favorable for the Bethesda system. The Bethesda system demonstrated a high positive predictive value, while the TIRADS system exhibited a high negative predictive value. The overall accuracy of the Bethesda system was slightly higher than that of the TIRADS system.

Numerous studies[7,22,23,32] have demonstrated that TIRADS exhibits a high level of sensitivity, specificity, and accuracy. However, the capacity of TIRADS to differentiate between benign and malignant nodules is contingent upon the size of the nodule. Moreover, the implementation of TIRADS in clinical practice is complex, and the categorization results may vary between sonographers for the same image. Consequently, FNAC may enhance the diagnostic precision of both benign and malignant thyroid nodules.

A number of studies have demonstrated that the incidence of false negative results for ultrasound-guided FNAC is less than 3%[1,33]. A review of 1,343 cytologic results of benign nodules revealed that the malignancy rate could reach as high as 29% in cases where ultrasound findings were suspicious, whereas it was only 0.6% when ultrasound results were normal[34]. Moreover, Liu and Huang[35] demonstrated a sensitivity of 83% (range 65–98%), specificity of 92% (range 72–100%), positive predictive value of 75% (range 50–96%), false negative rate of 5% (range 1–11%), and false positive rate of 5% (range 0–7%).

Tan *et al*.[32] demonstrated that the use of both the high-resolution ultrasound TIRADS classification and the Bethesda classification in conjunction with one another can enhance the accuracy of diagnosing malignant thyroid nodules. Fawzy *et al*.[22] employed a statistical analysis to assess the sensitivity and specificity of TIRADS and Bethesda classification together. Their findings indicated that both sensitivity and specificity had increased to 90.8% and 98%, respectively. Khan *et al*.[25] validated the association between TIRADS categories and the final cytology results of thyroid nodules. This correlation provides clinicians with a reliable approach to assessing the likelihood of malignancy in thyroid nodules by considering their ultrasound characteristics. The TIRADS categorization system enables physicians to make more informed decisions regarding the necessity of additional diagnostic testing, such as FNAC.

Limitations

The current study was conducted at a single center, which may limit the generalizability of the findings to broader populations. The relatively small sample size of patients may also affect the robustness of the statistical analysis. Furthermore, there is an inherent limitation in comparing TIRADS and Bethesda systems, as they are fundamentally different diagnostic tools with different criteria and interpretations. This difference may have contributed to the poor concordance observed between the two systems. Finally, our study did not consider the potential impact of interobserver variability in the interpretation of sonographic and cytological findings, which could influence the accuracy of the diagnostic assessments.

CONCLUSION

In conclusion, our study highlights the diagnostic challenges associated with solitary and dominant thyroid nodules by comparing TIRADS criteria with FNAC using the Bethesda system. While TIRADS showed good discrimination between malignant and benign nodules, the Bethesda system showed a slightly higher overall diagnostic accuracy. However, the poor concordance between the two systems suggests that they may complement rather than replace each other in clinical practice. These findings underscore the importance of using a multimodal approach in the evaluation of thyroid nodules to improve diagnostic accuracy, reduce the number of unnecessary surgical procedures, and avoid missing malignant nodules. Further studies with larger, more diverse populations and standardized protocols are needed to validate these findings and to explore the potential integration of the TIRADS and Bethesda systems in the management of thyroid nodules.

CONFLICT OF INTEREST

There are no conflicts of interest.

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