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THE ROLE OF USG IN DIFFERENTIATING BENIGN AND MALIGNANT THYROID NODULES

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ABSTRACT

Thyroid nodules are among the most common endocrine disorders and present a significant diagnostic challenge. In recent decades, the incidence of thyroid cancer has increased globally, largely due to improved detection methods and widespread imaging use. According to 2024 global data, thyroid cancer constitutes a notable proportion of endocrine malignancies and occurs more frequently in women than in men, making gender an important factor in diagnosis and management.

Purpose. To evaluate the diagnostic value of ultrasonography in differentiating benign and malignant thyroid nodules.

Materials and methods. This retrospective observational study included a total of **90 participants**. All patients underwent ultrasonographic evaluation between January 2024 and December 2025. The study population with thyroid nodules consisted of **78 females (91.8%) and 7 males (8.2%),** demonstrating a clear predominance of the disease among women. In contrast, the control group included **3 females and 2 males**, showing a more balanced gender distribution among healthy individuals. The overall mean age of the study population was **42.35 ± 4.1 years** (range, 14–70 years). The high frequency of thyroid nodules observed in female patients is consistent with known

epidemiological patterns, while the relatively lower number of male patients reflects the reduced prevalence of thyroid pathology in men.

All patients were examined using high-resolution gray-scale ultrasonography with a linear transducer operating at a frequency of 15 MHz, ensuring detailed visualization of thyroid structures. Each detected nodule was assessed based on standardized ultrasonographic criteria, including maximum size (mm), echogenicity (hypoechoic, isoechoic, hyperechoic), margin characteristics (regular or irregular), internal composition (solid, cystic, or mixed), presence of microcalcifications, and vascularity patterns. Nodules demonstrating suspicious ultrasonographic features underwent ultrasound-guided fine-needle aspiration biopsy (FNAB).Based on histopathological results, nodules were classified as benign or malignant. For further analysis, patients were divided into three age groups (≤30 years, 31–50 years, and >50 years) to evaluate age-related differences in nodule characteristics and malignancy risk. Statistical analysis was performed to compare ultrasonographic features between groups, with $p < 0.05$ considered statistically significant. At the time of presentation, the clinical complaints of the 85 patients were recorded. The majority of patients, 45 (52.9%), reported a palpable mass or nodule in the neck. Fifteen patients (17.6%) experienced difficulty swallowing (dysphagia), while 12 patients (14.1%) described a sensation of pressure or fullness in the neck. Voice changes or hoarseness were reported in 5 patients (5.9%), likely related to nodules affecting the nearby recurrent laryngeal nerve. Additionally, 8 patients (9.4%) were asymptomatic, with thyroid nodules detected incidentally during imaging performed for unrelated conditions. These clinical findings were documented retrospectively from patient records at the time of initial evaluation and provided context for the subsequent ultrasonographic and histopathologic assessments.

Results. A total of 90 patients with thyroid nodules were included in this retrospective observational study. Among them, 81 (90.0%) were female and 9 (10.0%) were male. The overall mean age of the cohort was 42.35 ± 4.1 years (range, 14–70 years). Based on predetermined age divisions, participants were stratified into three groups: Group 1 (≤30 years) with 22 patients (24.4%), Group 2 (31–50 years) with 40 patients (44.4%), and Group 3 (>50 years) with 28 patients (31.1%). Age distribution by gender showed that younger patients were more predominantly female, whereas males were more represented in the older age group (Table 1).

Table 1
Patient distribution by age group and gender

Age group	Total patients	Female	Male
14-30 years	22	20 (90.9%)	2 (9.1%)
31-50 years	40	36 (90.0%)	4 (10.0%)

50-70 years	28	25 (89.3%)	3 (10.7%)
Total	90	81 (90.0%)	9 (10.0%)

Ultrasonographic evaluation identified a total of **85 thyroid nodules among 90 patients,** with each nodule corresponding to a single patient. Among the study population, **5 patients showed no thyroid nodules and were considered ultrasonographically normal**, while the remaining **85 patients each presented a single thyroid nodule.** The mean nodule size across the cohort ranged from **6 to 11 mm**. A detailed analysis of nodule characteristics, including echogenicity, contours, internal composition, presence of calcifications, and vascularity patterns, revealed significant differences between nodules that were later classified as benign and malignant based on cytological and histopathological findings.

Table 2
Distribution of thyroid nodules according to TI-RADS categories

Category	Number of patients	Percentage (%)
TR0	5	5.6
TR1	11	12.2
TR2	24	26.7
TR3	28	31.1
TR4	15	16.7
TR5	7	7.8
Total	90	100.0

The distribution of patients according to TI-RADS classification showed that 5 individuals (5.6%) had no detectable thyroid nodules (TR0). Among patients with nodules, the majority were classified as TR3 (31.1%), followed by TR2 (26.7%). High-risk categories (TR4 and TR5) accounted for 24.5% of cases, indicating a considerable proportion of nodules with suspicious ultrasonographic features requiring further evaluation.

According to ultrasonographic assessment, **hypoechoic nodules** were the most frequent, accounting for **60 cases (70.6%),** followed by **hyperechoic nodules** in **16 cases (18.8%)** and **isoechoic nodules** in **9 cases (10.6%)**. In terms of contour characteristics, **regular borders** were observed in **55 nodules (64.7%)**, whereas **irregular contours** were identified in **30 nodules (35.3%),** the latter being more commonly associated with malignant outcomes. Microcalcifications were present in **15 nodules (17.6%)** and absent in **70 nodules (82.4%)**, with a noticeably higher frequency among nodules that were subsequently confirmed as malignant. Evaluation of vascularity patterns demonstrated that **20 nodules (23.5%) were avascular, 25 nodules (29.4%) showed moderate vascularity,** and **16 nodules (18.8%) exhibited increased intranodular**

vascularity. Increased vascularity was more frequently associated with malignant histopathological findings. Overall, ultrasonographic features such as hypoechogenicity, irregular contours, presence of microcalcifications, and increased vascularity were strongly correlated with malignancy, supporting their diagnostic value in differentiating benign and malignant thyroid nodules.

Table 3
USG characteristics of Thyroid Nodules among patients

Feature	Signs	Number (n)	Percentage (%)
Echogenecity	Hypoechoic	60	70.6
	Isoechoic	9	10.6
	Hyperechoic	16	18.8
Contours	Regular	55	64.7
	Irregular	30	35.3
Microcalcifications	Present	15	17.6
	Absent	70	82.4
Composition	Avascular	20	23.5
	Moderately	25	29.4
	Increased	16	18.8

Echogenicity analysis showed that hypoechoic nodules were the most frequent finding, accounting for 60 cases (70.6%), while isoechoic and hyperechoic nodules were considerably less common. Regarding contours, regular margins predominated with 55 cases (64.7%), whereas irregular contours were less frequently observed. Microcalcifications were present in a minority of nodules (17.6%), with the majority showing no calcifications (82.4%). In terms of vascularity and composition, moderately vascular nodules were the most common subtype, while increased vascularity represented a smaller proportion of cases.

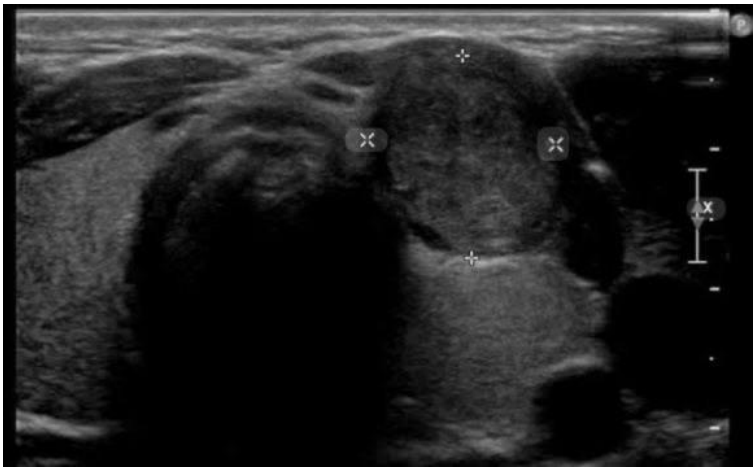

Image 1. Patient: Z, Age: 32 years. USG reveals a well-defined, round-shaped hypoechoic thyroid nodule measuring approximately 1.0×1.0 cm with smooth and regular margins.

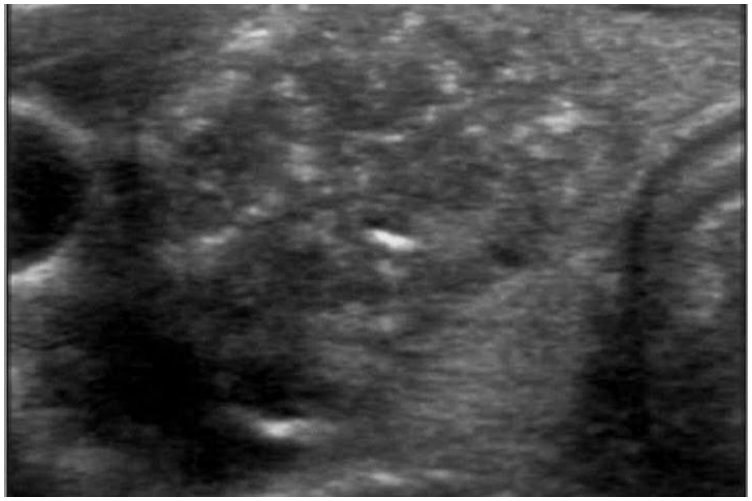

Image 2. Patient: X, Age: 28 years. USG reveals an irregularly shaped thyroid nodule with ill-defined margins, containing evident microcalcifications.

A total of 58 nodules (56.9%) were subjected to ultrasound-guided fine-needle aspiration biopsy (FNAB) based on pre-defined ultrasonographic risk criteria. Histopathological classification revealed:

Benign in 31 nodules (53.4%), Atypia/follicular lesion of undetermined significance in 9 nodules (15.5%), Follicular neoplasm/suspicious for follicular neoplasm in 6 nodules (10.3%), Suspicious for malignancy in 7 nodules (12.1%), Malignant in 5 nodules (8.6%).

Of the 22 nodules classified as categories V and VI, histopathological confirmation after surgical excision was available in all cases. Malignancy was confirmed in 20 nodules (90.9%) and included papillary carcinoma in 18 cases and follicular carcinoma in 2 cases. Two nodules originally classified as V were ultimately benign on histopathology (follicular adenoma).

Malignancy rates demonstrated a clear association with age (Table 3). In Group 1 (≤30 years), only 2 of 15 biopsied nodules (13.3%) were malignant. In Group 2 (31–50 years), 7 of 25 biopsied nodules (28.0%) proved malignant. The highest malignancy rate was observed in Group 3 (>50 years), where 11 of 18 biopsied nodules (61.1%) were malignant. Statistical comparison showed a significant difference in malignancy frequency across age groups ($p < 0.01$).

Women constituted the majority of patients with benign nodules, whereas men represented a disproportionately higher share of malignant cases (malignant nodules in males: 8 of 15 biopsied nodules, 53.3%; in females: 12 of 43 biopsied nodules, 27.9%; $p = 0.04$). This gender difference in malignancy prevalence persisted even after age stratification.

Table 3
Histopathological Classification of Thyroid Nodules

Histopatology	Signs	Number of Nodules	Percentage(%)
Malignant	Papillary	18	21.2
	Follicular	2	2.4
	Medullary	0	0
Benign	Colloid	30	35.5
	Follicular	20	23.5
	Hyperplastic	10	11.8

Analysis of ultrasonographic predictors showed that nodules with irregular margins had a malignancy rate of 45.8% (11/24) versus 22.5% (9/40) in nodules with regular margins ($p = 0.03$). Nodules exhibiting microcalcifications had a malignancy frequency of 50.0% (10/20) compared to 25.0% (10/40) in those without ($p = 0.02$). High intranodular vascularity was also significantly associated with malignant histology (malignancy in 46.7% of high-vascularity nodules vs. 23.1% in low/absent vascularity, $p = 0.04$). Solid nodules had higher malignancy rates than cystic or mixed nodules (37.7% vs. 18.2%, $p = 0.05$).

The mean size of malignant nodules was 24.3 ± 8.2 mm, significantly larger than benign nodules, which averaged 17.1 ± 6.5 mm ($p < 0.001$). When categorizing nodules by size, those >20 mm demonstrated a malignancy rate of 42.1%, whereas nodules ≤20 mm had a malignancy rate of 25.3%.

Conclusion. The results of the present study demonstrate that thyroid nodules represent a common clinical finding, particularly among women, confirming previously reported epidemiological trends indicating a higher incidence in females [1,2]. However, despite this higher prevalence, the likelihood of malignancy was proportionally greater in male patients, highlighting the importance of careful evaluation regardless of overall incidence rates. Age-related analysis revealed a clear pattern in which the risk of malignancy increased progressively with advancing age, with patients older than 50 years showing the highest rates of malignant transformation and more aggressive ultrasonographic features.

Ultrasonographic assessment proved to be a highly effective diagnostic approach, allowing for detailed characterization of nodules based on structural and vascular features. In particular, hypoechogenicity, irregular or ill-defined margins, microcalcifications, and increased intranodular vascularity were strongly associated with malignant outcomes, which is consistent with established diagnostic criteria in current clinical guidelines. These findings reinforce the role of ultrasonography not only as a screening tool but also as a key method for malignancy risk stratification.

The use of ultrasound-guided fine-needle aspiration biopsy significantly improved diagnostic accuracy, enabling reliable differentiation between benign and malignant nodules while minimizing unnecessary surgical procedures. The application of the Bethesda classification system further contributed to

standardized interpretation of cytological findings and facilitated appropriate clinical decision-making [6].

Additionally, the study demonstrated that nodule size and internal composition play an important role in predicting malignancy, with larger and predominantly solid nodules showing a higher probability of cancer. The observed relationship between tumor characteristics and malignancy risk emphasizes the importance of a comprehensive and systematic ultrasonographic evaluation.

Overall, the integration of ultrasonography with histological assessment and demographic factors such as age and gender provides a reliable and clinically effective approach for the diagnosis and management of thyroid nodules. Early identification of high-risk nodules through these combined methods can significantly improve patient outcomes, reduce diagnostic uncertainty, and optimize treatment strategies.

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