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Research Article

The significance of ultrasonography and color Doppler in diagnosing thyroid nodules and their association with ultrasound-guided FNAC approaches.

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Abstract: ***Introduction:*** Thyroid nodules are among the most common endocrine disorders encountered in clinical practice, with their detection rates increasing due to widespread use of high-resolution imaging. While the majority are benign, 5–15% harbor malignancy. Accurate differentiation between benign and malignant nodules is essential to avoid unnecessary interventions while ensuring timely management of cancerous lesions. Ultrasonography (USG) with Color Doppler has emerged as a valuable non-invasive tool for characterizing thyroid nodules based on morphological and vascular features.**Objectives:** This study aimed to evaluate the diagnostic significance of high-resolution ultrasonography and Color Doppler imaging in the assessment of thyroid nodules and to determine the association of specific sonographic features with ultrasound-guided fine-needle aspiration cytology (FNAC) results for differentiating benign from malignant thyroid nodules.**Methods:** A cross-sectional study was conducted among 140 patients presenting with thyroid nodules. All participants underwent detailed grayscale USG and Color Doppler evaluation, followed by USG-guided FNAC. Various sonographic parameters (size, shape, margins, echogenicity, calcifications, halo, vascularity, nodal involvement, and extrathyroidal extension) were analyzed and correlated with cytopathological findings using the Bethesda System. Diagnostic performance metrics including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated.**Results:** Out of 140 nodules, 90.7% were benign and 9.3% were malignant. Malignant nodules were significantly associated with taller-than-wide shape (69.2%), poorly defined margins (76.9%), marked hypoechogenicity (61.5%), microcalcifications (46.2%), nodal involvement (76.9%), extrathyroidal extension (30.8%), and central vascularity (76.9%). These features demonstrated high diagnostic accuracy (90–95%) with strong statistical significance ($p<0.001$).**Conclusion:** Ultrasonography combined with Color Doppler is a reliable non-invasive modality for risk stratification of thyroid nodules. Specific sonographic features show excellent correlation with FNAC results and can effectively guide clinical decision-making, reducing unnecessary biopsies while identifying high-risk lesions.

Keywords: Thyroid nodules, Ultrasonography, Color Doppler, FNAC, Thyroid malignancy, Diagnostic accuracy

INTRODUCTION

Thyroid nodules represent the most prevalent endocrine disorders that physicians acknowledge in their patients, and their occurrence rate has grown because clinicians now use high-resolution imaging technology more than ever previously.(1) Most thyroid nodules are benign and not cancerous, but healthcare professionals need to conduct accurate diagnostic tests since 5 to 15 percent of these cases possibly harbor undetected tumors.(2) Physicians now use ultrasonography (USG) as their key strategy to examine thyroid nodules as the technique provides non-invasive testing that costs less and is reachable everywhere while it can identify both minor and hidden medical conditions.(3)

Ultrasound with high resolution delivers extensive details about the dimensions, makeup, echogenic properties, borders, calcifications, and appearance of thyroid nodules.(4) The availability of hypoechogenicity and irregular margins together alongside microcalcifications and a taller-than-wide appearance have revealed strong correlation with malignant thyroid lesions. Recent research indicates that combining such concerning ultrasound characteristics greatly strengthens the ability to predict thyroid cancer.(5)

The use of Color Doppler ultrasonography raises diagnostic potential as it examines the vascular structures in thyroid nodules. The research shows that cancerous tumors display higher intramodular vascularity and greater resistive index values together with unusual plasticity index results. Doppler imaging allows the

disparity between benign hyperplastic nodules and neoplastic lesions by way of blood flow assessment. Studies have confirmed that Color Doppler exhibits high sensitivity and specificity for discovering malignant thyroid nodules that makes it a crucial tool for traditional ultrasonography.

Cytological assessment remains essential for confirming final diagnosis of thyroid nodules even though major progress in imaging technology. The gold standard for measuring thyroid nodules through barely invasive testing procedures is currently USG-guided FNAC.(6) The FNAC technique helps doctors reach better diagnosis results since it permits them to take specific tissue samples belonging to ultrasound-identified problem areas, which contributes to fewer required operations and better patient treatment.(7) The multiple studies have revealed that USG-guided FNAC achieves high diagnostic accuracy as it correctly identifies both benign and malignant thyroid nodules including high sensitivity and specificity.(4)

The combination of ultrasonography with Color Doppler observations and FNAC testing offers medical professionals with advanced diagnostic capabilities and better methods for examining thyroid nodule risk.(7) The sonographic features of a nodule together with its cytological outcomes facilitate physicians to determine which nodules are found the highest danger while selecting their biopsy targets and treatment approaches.(8) The use of standardized presentation systems TI-RADS has strengthened both the reproducibility and reliability of ultrasound evaluations employed to assess thyroid nodules.(2)

The current research analyses the role of ultrasonography together with Color Doppler imaging for thyroid nodule identification and establishes their diagnostic value through comparison with ultrasound-guided fine-needle removal cytology results which determine their accuracy in identifying between benign and malignant thyroid conditions.

MATERIALS AND METHODS

Study design and study setting:
The study took place at Sree Mookambika Institute of Medical Sciences , its Radiodiagnosis Department and Pathology Department and Surgery Department during a period of January 2026 to June 2026.

Study participants
The research included patients those presented thyroid swelling or had clinical indications of thyroid nodules at the hospital's outpatient and inpatient departments during the research time frame. The study recognized participants who were at least 18 years old as well as who wanted to take part in the research examination. The study excluded patients who underwent previous thyroid surgery or who had undergone either medical or unintentional contact with ionizing radiation in the neck area or who were getting treatment for existing thyroid cancer or who had blood clotting disorders that produced fine needle aspiration unsafe or who chose not to sign the informed consent document.

Study Tool
Data was collected using a semi-structured proforma designed to collect the research objectives. The tool collected data about sociodemographic information and complete medical history alongside with details about current health status and physical examination outcomes and laboratory tests and ultrasound findings and Color Doppler vascular examinations and cytopathological data from FNAC.

Study Procedure
The research initiated after receiving approval from the Institutional Ethics Committee. The written informed consent from acquired from all participants prior to start the research.

All recruited subjects went through high-resolution ultrasonographic examination of the thyroid gland using a high-frequency linear array transducer installed with Color Doppler imaging capability. The examination required participants to lie on their backs with their necks partially extended backward that helped clinicians see their thyroids better. The scanning procedure used both transverse and longitudinal scanning approaches.

The assessment of each thyroid nodule consisting of total count, exact anatomical position, measurement of its size, examination of internal structure, analysis of echogenicity, evaluation of margin features, resolution of its shape, assessment of peripheral halo presence, identification of cystic degeneration, assessment of calcific foci, and analysis of any extrathyroidal extension. The evaluation consisted of assessment of cervical lymphadenopathy presence. The study aimed on sonographic characteristics that indicate malignant transformation, that consist of marked hypoechogenicity, irregular or micro lobulated margins, microcalcifications, taller-than-wide configuration, and disrupted peripheral halo.

A Color Doppler assessment was carried out to evaluate the vascular structure of the nodules.
The study identified four vascularity patterns which included
Type 1 with no vascularity
Type 2 with vascularity around the edges
Type 3 with vascularity inside the nodules and
Type 4 which combined both peripheral and intramodular vascularity.

Using grayscale ultrasonography and Doppler vascular patterns, nodules are classified into three types: benign,

suspicious, and malignant, based on validated sonographic criteria and TI-RADS recommendations.

The procedure of ultrasound-guided fine needle aspiration cytology (USG-guided FNAC) conducted under complete sterile conditions with staff members using a disposable 22–23-gauge needle that attached to a 10- or 20-mL syringe. The participants received directions to maintain silence and avoid swallowing throughout the time of needle insertion because this may help reduce procedure-related artifacts and protect nearby body parts from damage. The researchers extracted matter from the study site which they then used to create glass slides that went through air drying and proper alcohol fixation procedures. The cytological samples received three different staining methodologies which consisting of May–Grunwald–Giemsa and Haematoxylin and Eosin and Papanicolaou staining methods. The results of cytopathological analysis trailed the Bethesda System for Reporting Thyroid Cytopathology which offers standardized reporting guidelines.

The diagnostic value of imaging techniques was evaluated of ultrasonographic and Doppler features which was contrasted with FNAC results to detect differences between benign and malignant thyroid nodules.

Data Analysis

The collected data were examined statistically after researchers inserted it into Microsoft Excel and proceeded to use SPSS version software version 27.0 for their analysis. The study exhibited quantitative variables as mean values with standard deviation, and qualitative variables were shown through frequency counts and percentage distributions.

The study examined the diagnostic effectiveness of grayscale ultrasonography and Color Doppler parameters using comparison with FNAC results for detecting malignant thyroid nodules. The researchers estimated sensitivity and specificity together with positive predictive value and negative predictive value and overall diagnostic accuracy. The study applied Chi-square test and Fisher's exact test to evaluate associations between individual sonographic variables and cytopathological results. To determine statistical significance a p-value limit of 0.05 was established.

RESULTS

Table 1: Baseline Characteristics, Clinical Findings, FNAC Results, and Histopathological Distribution of Study Population (N = 140)

Variable	Category	Frequency (n)	Percent (%)
Age Group	<20 years	1	0.7
	21–30 years	27	19.3
	31–40 years	74	52.9
	>41 years	38	27.1
Gender	Female	100	71.4
	Male	40	28.6
Number of Nodules	Solitary	92	65.7
	Multiple	48	34.3
Malignancy Status	Benign	127	90.7
	Malignant	13	9.3
FNAC Result	Benign	120	85.7
	Intermediate	9	6.4
	Malignant	11	7.9
Benign Histopathology	Colloid goiter	44	31.4
	Hyperplastic nodule	29	20.7
	Nodular goiter	29	20.7
	Benign follicular lesion	15	10.7
	Hashimoto thyroiditis	10	7.1
Malignant Histopathology	Papillary carcinoma	9	6.4
	Follicular carcinoma	2	1.4
	Medullary carcinoma	1	0.7
	Non-Hodgkin lymphoma	1	0.7

The demographic profile of the study exhibited that females made up 71.4% of the participants, with the largest age group being 31 to 40 years old at 52.9%. Single thyroid nodules were recognized a little more frequently than multiple nodules, occupying nearly two-thirds or 65.7% of the cases. Most nodules (90.7%) were benign, while only about 9.3% of the nodules were malignant. The FNAC outcomes also showed a majority of lesions identified as benign (85.7%), with intermediate or malignant malignancies being 6.4% and 7.9% of the cases, respectively. Among histologically benign diagnoses, colloid goiter was classified as the most frequent lesion detected (31.4%), followed by hyperplastic nodule and nodular goiter (20.7% each). On the other hand, papillary carcinoma was the most typical histological malignant type (6.4%), however other entities, such as follicular carcinoma, medullary carcinoma, and non-Hodgkin lymphoma, were somewhat rare.

Table 2: Ultrasonographic Characteristics of Thyroid Nodules (N = 140)

Variable	Category	Benign n (%)	Malignant n (%)
Number of Nodules	Multiple	43 (33.9)	5 (38.5)
	Solitary	84 (66.1)	8 (61.5)
Size Group	<1 cm	14 (11.0)	0 (0.0)
	1–2 cm	72 (56.7)	5 (38.5)
	>2 cm	41 (32.3)	8 (61.5)
Shape	Taller than wide	8 (6.3)	9 (69.2)
	Wider than tall	119 (93.7)	4 (30.8)
Margin	Smooth	101 (79.5)	0 (0.0)
	Lobulated	20 (15.7)	3 (23.1)
	Poorly defined	6 (4.7)	10 (76.9)
Peripheral Halo	<50%	39 (30.7)	12 (92.3)
	≥50%	88 (69.3)	1 (7.7)
Echogenicity	Anechoic	6 (4.7)	0 (0.0)
	Hyperechoic	49 (38.6)	0 (0.0)
	Hypoechoic	32 (25.2)	2 (15.4)
	Isoechoic	23 (18.1)	0 (0.0)
	Markedly hypoechoic	0 (0.0)	8 (61.5)
	Mixed echogenicity	17 (13.4)	3 (23.1)
Internal Content	Cystic	12 (9.4)	0 (0.0)
	Predominantly cystic	25 (19.7)	0 (0.0)
	Predominantly solid	43 (33.9)	3 (23.1)
	Solid	47 (37.0)	10 (76.9)
Calcification Type	Absent	103 (81.1)	7 (53.8)
	Macrocalcification	22 (17.3)	0 (0.0)
	Microcalcification	2 (1.6)	6 (46.2)
Nodal Involvement	Absent	120 (94.5)	3 (23.1)
	Present	7 (5.5)	10 (76.9)
Extrathyroidal Extension	Absent	127 (100.0)	9 (69.2)
	Present	0 (0.0)	4 (30.8)
Vascularity	Absent	10 (7.9)	0 (0.0)
	Central	11 (8.7)	10 (76.9)
	Mixed	35 (27.6)	1 (7.7)
	Peripheral	71 (55.9)	2 (15.4)

It can clearly be observed that there are some noticeable differences between benign and malignant thyroid nodules in ultrasonography. Single nodules were detected more frequently in both benign and malignant groups. Over 50% of malignant nodules (61.5%) were present larger than 2 cm compared to benign ones at 56.7%. A "taller-than-wide"

morphology ratio was more strongly related with a malignant outcome, and most benign nodules exhibited the opposite (93.7%). Poorly outlined margins were characteristically noticed at a greater frequency in malignant lesions (76.9%), while smooth margins were observed in most of the benign cases (79.5%).

Ultrasonography patterns of benign nodules demonstrated the development of a halo, maximum half the border, and a very minimal echo feature, whereas the central region was hypoechoic and solid and was representative of a particle. With malignant types, calcification was commonly found. Nodal involvement and extrathyroidal extension were discovered at the highest rate in malignant lesions, confirming a major aggression. Central vascularity was revealed with a high positivity rate in malignant nodules (76.9%); peripheral vascularity was mainly seen in the benign groups (55.9%). Overall, the pattern signifies malignancy in nodules when the specified features are observed, involving a taller-than-wide shape, unclear margins, solid nature, marked hypoechogenicity, microcalcifications, participation of lymph nodes, central blood flow, and extension outside the capsule.

Table 3: Distribution of Diagnostic Accuracy of Various USG Characteristics in Diagnosing Malignancy When Compared to FNAC

Ultrasound Characteristics	Sensitivity	Specificity	PPV	NPV	Diagnostic Accuracy	P-value
Solitary nodules	63.6% (7/11)	34.1% (44/129)	7.6% (7/92)	86.3% (44/51)	36.4% (51/140)	0.73
Multiple nodules	36.4% (4/11)	65.9% (85/129)	8.3% (4/48)	92.4% (85/92)	63.6% (89/140)	0.73
Size <1 cm	0.0% (0/11)	89.1% (115/129)	0.0% (0/14)	91.3% (115/126)	82.1% (115/140)	0.518
Size 1–2 cm	45.5% (5/11)	44.2% (57/129)	6.5% (5/77)	91.9% (57/62)	44.3% (62/140)	0.518
Size >2 cm	54.5% (6/11)	66.7% (86/129)	12.2% (6/49)	94.5% (86/91)	65.7% (92/140)	0.518
Taller than wide shape	72.7% (8/11)	93.0% (120/129)	47.1% (8/17)	97.6% (120/123)	91.4% (128/140)	<0.001
Wider than tall shape	27.3% (3/11)	7.0% (9/129)	2.4% (3/123)	75.0% (9/12)	8.6% (12/140)	<0.001
Poorly defined margins	72.7% (8/11)	93.8% (121/129)	50.0% (8/16)	97.6% (121/124)	92.1% (129/140)	<0.001
Lobulated margins	27.3% (3/11)	84.5% (109/129)	13.0% (3/23)	94.8% (109/117)	80.0% (112/140)	<0.001
Smooth margins	0.0% (0/11)	21.7% (28/129)	0.0% (0/101)	71.8% (28/39)	20.0% (28/140)	<0.001
Peripheral halo <50%	100% (11/11)	69.0% (89/129)	21.6% (11/51)	100% (89/89)	71.4% (100/140)	<0.001
Peripheral halo ≥50%	0.0% (0/11)	31.0% (40/129)	0.0% (0/89)	84.7% (40/51)	28.6% (40/140)	<0.001
Hypoechoic	18.2% (2/11)	75.2% (97/129)	5.9% (2/34)	94.2% (97/103)	70.7% (99/140)	<0.001
Markedly hypoechoic	54.5% (6/11)	98.4% (127/129)	75.0% (6/8)	96.2% (127/132)	95.0% (133/140)	<0.001
Mixed echogenicity	27.3% (3/11)	86.8% (112/129)	15.0% (3/20)	95.7% (112/117)	82.1% (115/140)	<0.001
Solid content	81.8% (9/11)	62.8% (81/129)	15.8% (9/57)	97.6% (81/83)	64.3% (90/140)	0.132
Predominantly solid content	18.2% (2/11)	66.7% (86/129)	4.3% (2/46)	93.5% (86/92)	62.9% (88/140)	0.132
Microcalcification	45.5% (5/11)	97.7% (126/129)	62.5% (5/8)	95.5% (126/132)	93.6% (131/140)	<0.001
Macrocalcification	0.0% (0/11)	83.7% (108/129)	0.0% (0/22)	90.8% (108/119)	77.1% (108/140)	<0.001
Nodal involvement present	72.7% (8/11)	93.0% (120/129)	47.1% (8/17)	97.6% (120/123)	91.4% (128/140)	<0.001
Extrathyroidal extension present	36.4% (4/11)	100% (129/129)	100% (4/4)	94.9% (129/136)	95.0% (133/140)	<0.001

Central vascularity	81.8% (9/11)	90.7% (117/129)	42.9% (9/21)	98.3% (117/119)	90.0% (126/140)	<0.001
Peripheral vascularity	9.1% (1/11)	44.2% (57/129)	1.4% (1/73)	83.8% (57/68)	41.4% (58/140)	<0.001
Mixed vascularity	9.1% (1/11)	72.9% (94/129)	2.8% (1/36)	94.0% (94/100)	67.9% (95/140)	<0.001

The rows in Table 3 clearly show that particular ultrasound features had good diagnostic accuracy for thyroid malignancy in comparison to FNAC results. Generally, a tall-to-wide ratio with irregular margins, microcalcifications, nodal involvement, intense central, significantly hypoechoic and extrathyroidal spread of the nodule significantly conferred high accuracy and an encouragingly sound, highly efficient feasibility for these features. The sensitivity and negative predictive value were 100% for halos of involvement under 50% (thus without including any no specificity, which is, 100% likelihood of malignancy associated with this feature). Positive extrathyroidal extension was seen to be 100% specific for malignancy, with maximum 100% positive predictive value (PPV). Other features, similar as those exhibited by nodules in concepts of size and multiple, were not significantly contributing to the diagnostic performance. This indicates that some particular sonographic features, particularly shape, margin, echogenicity, calcification pattern, nodal involvement, and vascularity, are vigorous predictors of thyroid malignancy.

DISCUSSION

The larger part of the patients (52.9%) belong among the 31–40-year age group, aligned with the high incidence of thyroid nodules in the Middle Ages as indicated by Tripura et al. (2024) and Boudina et al. (2024). Majority of the subjects appeared females; however, the male-to-female ratio was about 1:2.5, suggesting an impact of the female hormone estrogen on the proliferation of thyroid cells, as echoed across various studies initiated in recent series.

Solitary nodule appeared higher in number (65.7%) as several studies such as Tripura et al. (2024) and Asmita et al. (2025) have suggested, even though the solitary nodules were potentially more likely to be malignant and require further sonographic study regardless of multiplicity. The rate of malignancy was nearly 9.3%, quite similar to 9.1% in the series stated by Tripura et al. (2024) as it was such as any typical series of clinically discovered solid nodules lying within 5–15% criminally. Based on FTAC, around 85.7% of the thyroid nodules were benign as per Bethesda System where malignant appeared 7.9% and undetermined were 6.4%, which come near to Boudina et al. (2024). Indeterminate malignancy rate was 28%-37% (Mehanna-Delia-Calkins et al, 2025), which additional explains the collective sonographic risk evaluation role within this subset. In South Asian populations facing regional iodine deficiency, colloid goiter was the most frequently seen benign nodule at 31.4%, followed by hyperplastic and nodular goiters, both at 20.7%. Papillary thyroid carcinoma was the most common malignant entity (6.4%), yet it is well recognized; carcinoma of medullary and primary thyroid lymphoma being a rarity (both 0.7%) compare correctly with their poor worldwide incidence.

Nodule number was similar between benign and malignant groups (solitary 66.1% vs. 61.5%) with no significant difference, which confirmed, similarly as noted by Tripura et al. (2024) and Asmita et al. (2025), that multiplicity per se has no discriminatory value. Malignant nodules were more likely to be >2 cm (61.5% vs. 32.3% benign), but Mehanna et al (2025) observed higher per-nodule malignancy rates in nodules <10 mm, inclined due to incidentaloma bias in the sense that size needs to be assessed in context.

A taller-than-wide orientation was observed in 69.2% of malignant tumors compared with only 6.3% of benign nodules, demonstrating growth across tissue planes rather than along natural thyroid architecture. Margins were poorly characterized in 76.9% of malignant cases and smooth margins were absent in all malignant cases confirming high negative predictive value. In 92.3% of malignant nodules, an incomplete peripheral halo was seen (<50% circumference), while complete halo was mostly benign, in line with Dhas et al. (2024) and Tripura et al. (2024).

Malignant nodules (61.5%) were the only ones exhibiting marked hypoechogenicity and benign nodules never demonstrated it. Benign nodules only revealed hyper echogenicity and isoechogenicity which is similar to the outcomes of Tripura et al., (2024) and Boudina et al., (2024). According to the general consensus, solid composition was seen in 76.9% of malignant nodules, whereas cystic lesions were shown to be benign only. Microcalcifications was noted in 46.2% of malignant nodules as compared to only 1.6% of benign nodules. Macrocalcifications were seen only in benign lesions. This signifies psammoma body formation and dystrophic calcification, respectively.

Lymph node metastases were identified in 76.9% of malignant cases (vs. 5.5% benign), which was a strong independent predictor which was confirmed by Abdalwahab et al. (2024) and Tripura et al. (2024) too. Extrathyroidal extension, observed in 30.8% of malignant nodules, was absent in all benign cases making it 100% specific for malignancy in this cohort, as reported by Boudina et al. (2024) and Dhas et al. (2024). On Doppler, central vascularity was higher in malignant nodules (76.9%), while peripheral vascularity was the

dominant benign pattern, indicating tumor-induced neoangiogenesis; mixed vascularity exhibited intermediate associations.

As independent predictors, nodule size and number did not perform well. Solitary status measured only 36.4% accurate (p=0.73). No size category attained statistical significance (p=0.518) with >2cm nodules only 65.7% accurate. These results are in line with Tripura et al. (2024) and Asmita et al. (2025) emphasizing that these features should not be used as solo diagnostic decision factors.

The sign, taller than wide, showed a sensitivity of 72.7%, specificity of 93.0%, NPV of 97.6%, and overall accuracy of 91.4% (p<0.001) similar to Tripura et al., 2024 and verified by Boudina et al., 2024. Poorly specified margins yielded the highest single feature accuracy of 92.1% (sensitivity 72.7%, specificity 93.8%, NPV 97.6%; p<0.001) similar to Tripura et al. (2024) at 92% and multivariate data from Abdalwahab et al. (2024). A peripheral halo <50% indicated 100% sensitivity and NPV; every malignant nodule displayed an incomplete halo with 71.4% overall accuracy (p<0.001), confirming its function as a sensitive exclusion criterion.

Marked hypoechogenicity was the strongest predictor of echogenicity with 95.0% accuracy (specificity 98.4%, PPV 75.0%; p<0.001), equivalent to Tripura et al. (2024). Solid internal content demonstrated high sensitivity (81.8%) but low specificity (62.8%) and failed to reach significance (p=0.132), demonstrating the prevalence of solid architecture in benign colloid goiters. Microcalcification exhibited a specificity of 97.7% and accuracy of 93.6% (p<0.001) and was one of the most specific particular features and an independent indication for FNAC even when alone as per Tripura et al. (2024) at 96% and Boudina et al. (2024).

Lymph node involvement was equivalent to the taller-than-wide sign in accuracy (91.4%) (sensitivity 72.7%, specificity 93.0%, NPV 97.6%; p<0.001), with a high NPV that supports reasonable follow-up in the absence of lymphadenopathy. Extrathyroidal extension exhibits a 100% specificity, PPV, and 95.0% overall accuracy (p<0.001), with a sensitivity of 36.4%. It is a pathognomonic indication of malignancy and requires surgical referral. Central vascularity displayed the best Doppler performance with sensitivity 81.8%, specificity 90.7%, NPV 98.3% and accuracy 90.0% (p<0.001) and compared well with Orakzai et al. (2026) with accuracy 89.2% and AUC 0.93. Peripheral and mixed vascularity had values of low accuracy (41.4% and 67.9%) in line with its usual benign associations in similar series.

CONCLUSION

The present study demonstrates that ultrasonography with colour Doppler is a reliable non-invasive tool for identification of thyroid nodules and assessment of risk of malignancy prior to FNAC. inadequately defined margins, taller-than-wide shape, marked hypoechogenicity, microcalcifications, nodal involvement, and central vascularity became the most significant predictors of malignancy, each having a diagnostic accuracy above 90% with strong statistical significance. Extrathyroidal extension was 100% specific for malignancy, a reliable indicator for surgical referral. In contrast, the size, number and internal content of nodules alone became poor predictors. Overall, the combination of a grayscale and Doppler based multifeature strategy in a structured reporting system can improve the accuracy of preoperative diagnosis, decrease the number of unnecessary biopsies and assist in the appropriate clinical management of thyroid nodules.

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