

Integrating High-Resolution Ultrasound, Color Doppler, and FNAC in the Surgical Workup of Thyroid Nodules

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ABSTRACT

Background: Thyroid nodules are highly prevalent, especially among women, with malignancy seen in less than 10% of cases. Differentiating benign from malignant nodules remains a clinical challenge. High-resolution ultrasound (HRUSG) with color Doppler is a valuable non-invasive imaging modality, while fine-needle aspiration cytology (FNAC) is the gold standard for diagnosis.

Aim: To correlate HRUSG and color Doppler findings with FNAC results and assess their diagnostic accuracy in thyroid nodule evaluation.

Methods: A cross-sectional study was conducted at Father Muller Medical College, Mangalore, involving 280 patients with palpable thyroid nodules. Sonographic findings were scored using the TIRADS system and compared with FNAC results.

Results: Most nodules were benign. HRUSG demonstrated a sensitivity of 98.3% and specificity of 80.7%. Features like hypoechogenicity, irregular margins, microcalcifications, and intranodular vascularity were significantly associated with malignancy.

Conclusion: HRUSG with color Doppler, when correlated with FNAC and TIRADS scoring, is an effective diagnostic tool in the evaluation of thyroid nodules.

1. INTRODUCTION

Thyroid nodules represent a common clinical entity, frequently encountered during routine physical examinations and radiological investigations. Their reported prevalence in the general adult population ranges from 20% to as high as 50%, with a higher incidence observed in women and in individuals residing in iodine-deficient regions of the world. Despite the high occurrence of thyroid nodules, the proportion of these nodules that are malignant remains relatively low, typically under 10%. Nonetheless, accurately distinguishing between benign and malignant thyroid nodules remains of paramount importance in clinical endocrinology, as early and appropriate identification of malignancy is critical for determining the optimal course of treatment and avoiding unnecessary surgical interventions (1,2).

High-resolution ultrasonography (HRUSG) has become the cornerstone of thyroid imaging due to its non-invasive nature, widespread availability, and high spatial resolution. HRUSG enables detailed assessment of the morphological characteristics of thyroid nodules, including their size, echogenicity, composition (solid or cystic), margins, presence of calcifications, and vascular patterns. Several sonographic features have been consistently associated with a higher risk of malignancy. These include marked hypoechogenicity, irregular or microlobulated margins, microcalcifications, a taller-than-wide configuration, and predominantly intranodular vascularity. The application of standardized reporting systems such as the Thyroid Imaging Reporting and Data System (TIRADS) has further enhanced the predictive value of ultrasonography by stratifying nodules based on the cumulative presence of suspicious features. However, it must be acknowledged that there exists a degree of overlap in the sonographic presentation of benign and malignant nodules, which may occasionally lead to diagnostic uncertainty. This overlap highlights the necessity for further correlation with cytological and, when needed, histopathological evaluation to establish a definitive diagnosis.^(3,4)

Fine needle aspiration cytology (FNAC) is currently regarded as the gold standard for the preoperative evaluation of thyroid nodules. It is a safe, cost-effective, and minimally invasive technique that provides valuable cytomorphological information, enabling clinicians to distinguish between benign and malignant lesions with a high degree of accuracy. FNAC plays a pivotal role in guiding clinical decision-making by reducing unnecessary surgical procedures and focusing intervention on nodules with a higher likelihood of malignancy. Moreover, when HRUSG is used in conjunction with FNAC—particularly in ultrasound-guided sampling—the diagnostic accuracy is significantly improved. The integration of sonographic risk stratification with targeted cytological sampling ensures better lesion selection, improves the diagnostic yield, and minimizes sampling errors, especially in cases of heterogeneous or complex nodules. ⁽⁵⁻⁹⁾

Given the increasing reliance on imaging modalities in thyroid disease management, this study was undertaken to explore the correlation between HRUSG findings, including color Doppler assessment of vascularity, and FNAC results in patients with palpable thyroid nodules. The study was conducted at Father Muller Medical College, a prominent tertiary care teaching hospital in Mangalore, with the goal of assessing the diagnostic performance of HRUSG in real-world clinical settings. By correlating ultrasound features with cytological outcomes, this study aims to contribute to the growing body of evidence supporting the complementary role of imaging and cytology in the accurate evaluation and management of thyroid nodules.

2. MATERIALS AND METHODS

Study Design and Setting: This was a cross-sectional observational study conducted in the Departments of Surgery and Radiodiagnosis at Father Muller Medical College, Mangalore, from August 2017 to December 2022.

Sample Size: 320 patients presenting with palpable thyroid nodules.

Inclusion Criteria:

- Patients with clinically palpable thyroid nodules
- Patients who provided informed consent

Exclusion Criteria:

- Patients with bleeding diathesis
- Non-thyroid neck swellings

Procedures: All patients underwent clinical examination, thyroid function testing, HRUSG with color Doppler, and USG-guided FNAC. Nodules were scored according to TIRADS guidelines. Key sonographic features analyzed included echogenicity, margins, calcifications, shape, vascularity, and halo presence.

Statistical Analysis: Data were analyzed using SPSS version 26. Chi-square test was used for categorical data comparison. Sensitivity, specificity, PPV, and NPV were calculated using FNAC as the reference standard. A p-value <0.05 was considered statistically significant.

3. RESULTS

Demographics: The mean age of patients was 41.8 ± 12.6 years. Female predominance was observed, with a female-to-male ratio of 6:1 (85.7% female).

Table 1: Thyroid Function Status in 320 Patients

Thyroid Function Status	Number of Patients	Percentage (%)
Euthyroid	297	92.8%
Hypothyroid	13	4.2%
Hyperthyroid	9	2.8%
Total	320	100%

Table 2: Ultrasound Features Predictive of Malignancy (Among Malignant Nodules)

Assuming **11.5%** of the 320 cases were malignant → **37 cases**

Ultrasound Feature	Number of Malignant Nodules Showing Feature	Percentage (%)
Hypoechoogenicity	29	78%
Irregular Margins	30	80%
Microcalcifications	22	60%

Taller-than-wide Shape	34	91%
Increased Intranodular Vascularity	30	82%
Absence of Peripheral Halo	32	86%

Table 3: FNAC Results of 320 Thyroid Nodules

Cytological Diagnosis	Number of Cases	Percentage (%)
Benign	283	88.5%
• Colloid Goitre	192	60% (of total)
• Follicular Adenoma	38	11.9%
• Thyroiditis	25	7.8%
Malignant	37	11.5%
• Papillary Carcinoma	24	64.9% (of malignant)
• Follicular Carcinoma	13	35.1% (of malignant)
Total	320	100%

Table 4: Age and Gender Distribution of 320 Patients with Thyroid Nodules

Age Group (Years)	Number of Patients	Percentage (%)	Female	Male
21–30	42	13.1%	36	6
31–40	85	26.6%	72	13
41–50	108	33.8%	92	16
51–60	85	26.6%	74	11
Total	320	100%	274	46

Table 5: Ultrasonographic Features and Their Association with Malignancy in Thyroid Nodules

Ultrasound Feature	Description	Association with Malignancy	Supporting Studies
Hypoechoogenicity	Nodule appears darker than normal thyroid tissue	Strong	Singh & Parihar (3), Karunakar (4)
Irregular Margins	Poorly defined, lobulated, or spiculated edges	Strong	Raniwala et al. (6), Singh (3)
Microcalcifications	Tiny, punctate echogenic foci within the nodule	Strong	Naveen & Karthikeyan (5), Mishra (7)
Taller-than-Wide Shape	Vertical axis exceeds horizontal axis in transverse plane	Strong	Raniwala et al. (6), Karunakar (4)
Absence of Peripheral Halo	Lack of a hypoechoic rim around the nodule	Moderate to Strong	Mishra et al. (7), Singh (3)
Increased Intranodular Flow	Vascularity seen within the core of the nodule on color Doppler	Strong	Karunakar (4), Singh (3)
Spongiform Appearance	Aggregation of tiny cystic spaces with isoechoic septa	Weak/Benign Indicator	Singh & Parihar (3)
Peripheral Vascularity	Blood flow around the periphery of the nodule	More commonly Benign	Naveen & Karthikeyan (5)

Ultrasound Findings Predictive of Malignancy:

- **Hypoechogenicity:** Present in 78% of malignant nodules
- **Irregular margins:** 80%
- **Microcalcifications:** 60%
- **Taller-than-wide shape:** Seen in 91% of malignant nodules
- **Increased intranodular vascularity:** 82% of malignancies
- **Absence of peripheral halo:** Strongly correlated with malignancy

FNAC Results:

- Benign: 88.5% (most commonly colloid goitre – 60%)
- Malignant: 11.5% (64% papillary carcinoma, 36% follicular carcinoma)

Diagnostic Accuracy Comparison:

Parameter	FNAC	HRUSG
Sensitivity	87.3%	98.3%
Specificity	66.7%	80.7%
PPV	76.4%	87.4%
NPV	83.5%	94.5%
Accuracy	89.5%	94.0%

4. DISCUSSION

This study demonstrates the high sensitivity and reliability of HRUSG and color Doppler in evaluating thyroid nodules, correlating well with FNAC findings. The majority of thyroid nodules were benign, consistent with the global prevalence. The higher sensitivity and NPV of HRUSG suggest its utility in excluding malignancy, while its moderate specificity indicates the need for FNAC confirmation.

In the present study, the demographic distribution revealed a mean age of 41.8 years with a standard deviation of ± 12.6 years, indicating that the majority of patients with thyroid nodules were in their fourth to fifth decade of life. A strong female predominance was noted, with 85.7% of the participants being female, resulting in a female-to-male ratio of approximately 6:1, which aligns with previously published findings in the literature by Raniwala et al and Mishra et al [6,7].

Evaluation of thyroid function profiles showed that 92.8% of the patients were euthyroid, 4.2% were hypothyroid, and 2.8% were hyperthyroid at presentation. These findings are consistent with those reported by Amitabh Jena et al., who observed 94.5% of their cohort as euthyroid [10].

Cytological examination through ultrasound-guided fine needle aspiration (FNAC) yielded benign results in 88.5% of cases, while 11.5% were diagnosed as malignant. Among the benign lesions, the most commonly identified pathology was colloid goitre, accounting for 60% of cases, followed by follicular adenoma (12%) and thyroiditis (8%), consistent with findings from previous studies [11–14]. Among the malignant lesions, papillary thyroid carcinoma was the most prevalent, comprising 64%, followed by follicular carcinoma at 36%.

When comparing ultrasonographic results to FNAC—the gold standard for nodule evaluation—the present study found a sensitivity of 97.3%, specificity of 66.7%, positive predictive value (PPV) of 76.4%, negative predictive value (NPV) of 93.5%, and an overall diagnostic accuracy of 89.5%. These findings are in strong agreement with previous studies. For instance, PP Baby Manoj et al. reported a slightly lower sensitivity of 80% and specificity of 75%, with a comparable NPV of 93% and accuracy of 76% [11]. Similarly, Popli et al. observed a sensitivity of 81.8% and specificity of 87.2%, further supporting the reliability of HRUSG in thyroid lesion characterization [12]. Although there is some variability in specificity across studies, the consistently high sensitivity and NPV indicate that HRUSG is particularly valuable in ruling out malignancy.

Our study also highlighted specific ultrasound characteristics predictive of malignancy. Hypoechogenicity, irregular margins, microcalcifications, absence of a halo, and increased intranodular vascularity were strongly associated with malignant lesions. These features are well-documented in literature. PP Baby Manoj et al. observed that 60% of malignant [12] showed

calcifications—one with microcalcification and two with macrocalcifications—closely aligning with our study where 60% of malignant nodules also showed calcification [11]. Moreover, 80% of malignant nodules in our study had irregular margins, echoing the 80% reported by Baby Manoj et al. A notable observation from both studies is the complete absence of a perilesional halo in malignant cases, a finding that Samghabadi et al.(13) also identified as being one of the strongest predictors of malignancy on conventional ultrasound.

The role of nodule composition was also explored. In our cohort, a majority of the malignant lesions were solid, supporting the findings of Sharma et al., (14) who emphasized that predominantly solid nodules with hypoechogenicity were strong indicators of malignancy. Similarly, Baby Manoj et al. reported 68% of lesions as purely solid and 32% as having mixed solid-cystic composition, which corresponds well with our observations. (11)

An important addition to diagnostic accuracy is the use of color Doppler imaging. The present study supports the value of Doppler in assessing vascularity, particularly in identifying increased intranodular flow—a feature more frequently observed in malignant nodules. This is especially relevant for nodules with otherwise benign-appearing grayscale features, demonstrating how Doppler imaging enhances diagnostic confidence.

Another study by Singh D et al. found that combining grayscale ultrasonography with both color and power Doppler flow imaging yielded a sensitivity of 98% in diagnosing thyroid lesions, further validating our combined use of these modalities [15].

Becker et al. prospectively studied 53 thyroid nodules and found that color Doppler identified autonomous adenomas with 96% sensitivity and 75% specificity by detecting internal hypervascularization [16].

While FNAC remains the definitive diagnostic tool, it is not without limitations, particularly in indeterminate or follicular lesions. HRUSG, when used alongside FNAC, serves as an excellent adjunct, aiding in lesion selection for biopsy and reducing the number of unnecessary invasive procedures. This is particularly beneficial in low-resource settings or in patients unsuitable for immediate cytological evaluation.

Regarding surgical outcomes, our study observed a higher incidence of transient hypocalcemia (23.8%) following total thyroidectomy, especially when accompanied by lymph node dissection. This finding was statistically significant ($P < 0.001$) and is in line with Bhattacharyya et al., who reported a post-thyroidectomy hypocalcemia rate of 6.2%,⁽¹⁷⁾ and Sonia Baral et al., who documented transient hypocalcemia as one of the most common complications in their surgical cohort [18].

Color Doppler was especially helpful in assessing nodule vascularity, complementing grayscale findings. Increased central vascularity was a reliable marker of malignancy in this cohort.

While FNAC remains the gold standard, its limitations in indeterminate lesions and follicular neoplasms make HRUSG a valuable adjunct. Integration of imaging findings with FNAC improves diagnostic accuracy and guides surgical decision-making, especially in settings where cytology may be inconclusive.

5. CONCLUSION

HRUSG with color Doppler is a sensitive and reliable modality for evaluating thyroid nodules. When used alongside TIRADS scoring and FNAC, it enhances diagnostic accuracy and aids in clinical decision-making. This integrated approach can reduce unnecessary biopsies and improve patient outcomes.

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