

Diagnostic Utility of Multiparametric Ultrasonography in the Evaluation of Diffuse and Nodular Thyroid Disorders

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Abstract:

Background: Thyroid disorders are among the most prevalent endocrine abnormalities, manifesting as diffuse or nodular glandular changes. Ultrasonography (USG) is widely utilized as the first-line imaging modality for thyroid evaluation due to its non-invasiveness and high resolution. The advent of multiparametric ultrasonography—encompassing gray-scale imaging, color Doppler, elastography, and contrast-enhanced ultrasound (CEUS)—has significantly improved lesion characterization, enabling better differentiation between benign and malignant pathologies. This study aims to evaluate the diagnostic utility of multiparametric ultrasonography in assessing parenchymal thyroid diseases and correlating sonographic findings with clinical and cytological outcomes.

Aims and Objectives: To assess the effectiveness of multiparametric ultrasonography in characterizing parenchymal thyroid diseases, including diffuse and nodular abnormalities, and to correlate ultrasonographic findings with cytopathological results for diagnostic validation.

Materials and Methods: This hospital-based prospective study was conducted in the Department of Radiology, Netaji Subhas Medical College and Hospital, Bihta, Patna. Seventy-five patients with clinically suspected thyroid disorders underwent multiparametric ultrasonography including gray-scale, color Doppler, and elastography assessment. Fine needle aspiration cytology (FNAC) or histopathology was performed where indicated. Imaging features were evaluated based on echotexture, vascularity, stiffness score, nodule size, margins, and calcifications. Correlation with cytological diagnosis was done for diagnostic accuracy analysis.

Results: Out of 75 patients, 42 presented with nodular thyroid disease and 33 with diffuse parenchymal involvement. Among nodular cases, 28 nodules were benign, 10 were indeterminate, and 4 were malignant on cytology. Elastography and Doppler findings showed significant correlation with malignant features—malignant nodules demonstrated higher stiffness and intranodular vascularity. In diffuse thyroid diseases, heterogeneous echotexture with increased vascularity was commonly seen in Graves' disease, while Hashimoto thyroiditis showed hypoechoic texture with coarse echotexture and reduced flow in later stages.

Conclusion: Multiparametric ultrasonography provides a comprehensive, non-invasive approach to evaluating thyroid parenchymal diseases. The combination of grayscale, Doppler, and elastography significantly enhances diagnostic confidence, especially in differentiating benign from malignant nodules and characterizing diffuse thyroid pathology. Routine use of multiparametric USG may reduce unnecessary FNACs and improve early disease recognition.

Keywords: Thyroid Nodules, Hashimoto's Thyroiditis, Graves' Disease, Ultrasonography, Elastography, Doppler, Multiparametric Imaging, FNAC.

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Introduction

Thyroid gland disorders constitute one of the most commonly encountered endocrine abnormalities worldwide, affecting individuals across all age groups and genders, with a higher prevalence among females [1]. These disorders can broadly be classified into diffuse parenchymal diseases and nodular thyroid diseases, each presenting with varying clinical manifestations, ranging from asymptomatic enlargement to overt thyrotoxicosis or hypothyroidism. The increasing incidence of thyroid nodules and autoimmune thyroiditis in

recent decades has necessitated the development of precise and non-invasive imaging modalities for accurate diagnosis, characterization, and follow-up [2,3].

Ultrasonography (USG) has long been established as the primary imaging modality for thyroid evaluation due to its safety, cost-effectiveness, real-time capability, and high spatial resolution. Gray-scale sonography provides detailed information on gland size, echotexture, and the presence of focal

lesions, while color Doppler imaging evaluates vascular flow patterns that can aid in differentiating between various types of thyroiditis and neoplastic conditions [4,5]. However, conventional gray-scale and Doppler evaluation alone may not always be sufficient to distinguish between benign and malignant nodules, particularly in indeterminate cases.

The advent of multiparametric ultrasonography, which integrates elastography and contrast-enhanced ultrasound (CEUS) with traditional gray-scale and Doppler imaging, represents a significant advancement in thyroid imaging [6]. Elastography assesses the stiffness or elasticity of tissue and has shown promising utility in identifying malignant nodules, which typically exhibit higher stiffness compared to benign ones. Similarly, CEUS can provide dynamic perfusion characteristics, although it is less widely available and operator-dependent [7].

Among diffuse thyroid diseases, Graves' disease and Hashimoto's thyroiditis are the most common. Graves' disease is characterized by a diffusely enlarged, hypoechoic gland with increased vascularity—often described as “thyroid inferno” on Doppler imaging [8]. In contrast, Hashimoto's thyroiditis typically demonstrates a coarse, heterogeneous echotexture with reduced vascularity in later stages and may evolve to form pseudonodules or mimic malignancy. Therefore, proper interpretation of sonographic patterns and integration of multiparametric data are critical to avoid misdiagnosis [9].

In the context of nodular thyroid disease, the need to differentiate malignant from benign nodules remains clinically important. Fine-needle aspiration cytology (FNAC) is the gold standard for evaluation, but it is invasive and not always required, especially for nodules with clearly benign sonographic features. Hence, the role of multiparametric USG becomes vital in stratifying the risk of malignancy and potentially avoiding unnecessary biopsies.

In this scenario, the present study was undertaken at Netaji Subhas Medical College and Hospital, Bihta, Patna, Bihar, with the objective of assessing the role of multiparametric ultrasonography—including gray-scale imaging, color Doppler, and elastography in evaluating parenchymal thyroid diseases. The study aimed to analyze the diagnostic features of various thyroid conditions and correlate sonographic findings with cytological or histopathological diagnoses for validation of imaging accuracy.

Aims and Objectives: The present study was conducted with the primary aim of evaluating the diagnostic utility of multiparametric ultrasonography in assessing parenchymal thyroid diseases, including both diffuse and nodular abnormalities.

Specific Objectives:

- To evaluate the sonographic characteristics of diffuse thyroid disorders such as Hashimoto's thyroiditis and Graves' disease using gray-scale and color Doppler imaging.
- To assess the utility of elastography in differentiating benign from malignant thyroid nodules based on tissue stiffness.
- To analyze and correlate imaging features with fine-needle aspiration cytology (FNAC) or histopathological diagnosis.
- To determine the added value of multiparametric ultrasonography in improving diagnostic confidence and reducing unnecessary FNAC procedures.
- To stratify thyroid lesions based on their imaging profiles and suggest a risk-based approach to clinical management.

Materials and Methods

This prospective hospital-based observational study was conducted in the Department of Radiology at Netaji Subhas Medical College and Hospital, Bihta, Patna, Bihar, over a period of 11 months from February 2023 to December 2023. The study included 75 patients who were referred for ultrasonographic evaluation of the thyroid gland with clinical suspicion of thyroid dysfunction, palpable neck swelling, goitre, or nodular lesions.

Inclusion Criteria

- Patients aged 15 years and above with clinical suspicion of thyroid disease.
- Patients presenting with diffuse thyroid enlargement, palpable nodules, or neck swelling.
- Patients who consented to undergo multiparametric ultrasonographic evaluation and cytological correlation where required.

Exclusion Criteria

- Patients with previous thyroid surgery or known thyroid malignancy under treatment.
- Patients with incomplete clinical or imaging data.
- Patients who declined or were unfit for FNAC or further evaluation.

Ultrasonography Protocol

All patients underwent detailed multiparametric ultrasonographic examination using a high-resolution ultrasound system equipped with a 7.5–12 MHz linear transducer. The imaging protocol included:

1. Gray-scale Imaging:

- Assessment of gland size, echotexture, margins, presence of nodules or calcifications.

- Evaluation of nodule characteristics including shape (taller-than-wide), margins, internal content (solid, cystic, mixed), echogenicity, and presence of microcalcifications.
2. **Color Doppler Evaluation:**
- Vascularity was assessed both in diffuse glandular disease and within nodules.
 - Flow patterns were categorized as peripheral, intranodular, mixed, or absent.
 - Increased central flow was considered suspicious for malignancy, while diffusely increased flow was suggestive of Graves' disease.
3. **Elastography (Strain-based technique):**
- Applied to focal nodules to assess tissue stiffness.
 - A 5-point elastography scoring system was used:
 - Score 1: Soft throughout the nodule
 - Score 2: Predominantly soft
 - Score 3: Mixed soft and stiff
 - Score 4: Predominantly stiff
 - Score 5: Stiff throughout
 - Scores ≥ 4 were considered suspicious for malignancy.

Cytopathological Correlation: Fine-needle aspiration cytology (FNAC) was performed under ultrasound guidance for all suspicious nodules based on standard sonographic criteria (solid, hypoechoic, irregular margins, microcalcifications, or increased stiffness). FNAC results were classified using the Bethesda system, where applicable.

In cases of diffuse thyroid disease, cytology was obtained only when features were atypical or suggestive of pseudonodules.

Data Recording and Analysis: All imaging and cytological findings were recorded in a predesigned data collection sheet. Sonographic diagnoses were compared with FNAC/histopathological results wherever available. Descriptive statistics were used for demographic variables. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy were calculated for elastography and Doppler findings using cytology/histopathology as the gold standard. A p-value <0.05 was considered statistically significant.

Results

This study included a total of 75 patients referred for ultrasonographic evaluation of suspected thyroid pathology. All patients underwent detailed multiparametric ultrasonography comprising gray-scale imaging, color Doppler assessment, and elastography. Fine-needle aspiration cytology (FNAC) or histopathology was available for all focal nodular lesions and selected diffuse thyroid diseases. Among the participants, the majority were females, with a female-to-male ratio of approximately 4:1. The age range varied between 18 to 68 years, with the peak incidence in the third and fourth decades. Clinical presentations included neck swelling, symptoms of hypothyroidism or hyperthyroidism, and incidentally detected thyroid enlargement. Imaging evaluation focused on both diffuse and nodular thyroid pathologies, with correlation to cytological diagnoses to evaluate diagnostic accuracy.

Table 1: Age-wise Distribution of Patients

Age Group (Years)	Frequency	Percentage (%)
15–30	13	17.3
31–45	30	40.0
46–60	24	32.0
>60	8	10.7

Table 1 shows that the majority of patients (40.0%) were in the 31–45 years age group, followed by the 46–60 years group (32.0%).

Table 2. Gender-wise Distribution of Cases

Gender	Frequency	Percentage (%)
Male	15	20.0
Female	60	80.0

Table 2 reveals a strong female preponderance, with females comprising 80.0% of the study population.

Table 3: Clinical Presentation of Patients

Clinical Features	Frequency	Percentage (%)
Neck swelling	61	81.3
Hypothyroid symptoms	24	32.0
Thyrotoxic symptoms	13	17.3
Incidental finding	10	13.3
Pain or pressure symptoms	5	6.7

Table 3 summarizes the primary symptoms. Neck swelling was the most common complaint (81.3%), followed by hypothyroid symptoms and thyrotoxicosis.

Table 4: Distribution of Thyroid Pathologies on USG

USG Diagnosis	Frequency	Percentage (%)
Hashimoto's thyroiditis	22	29.3
Graves' disease	11	14.7
Solitary thyroid nodule	28	37.3
Multinodular goitre	14	18.7

Table 4 shows that diffuse thyroid disease accounted for 44.0% of cases, while nodular disease was seen in 56.0%.

Table 5: Echotexture Patterns in Diffuse Thyroid Disease

Diagnosis	Echotexture	Frequency	Percentage (%)
Hashimoto's thyroiditis	Coarse & heterogeneous	18	81.8
Graves' disease	Hypoechoic & uniform	9	81.8

Table 5 shows typical sonographic appearances. Hashimoto's thyroiditis showed heterogeneous, coarse echotexture, while Graves' disease showed diffuse hypoechogenicity with increased vascularity.

Table 6: Doppler Vascularity in Diffuse Thyroid Disease

Diagnosis	Vascular Pattern	Frequency	Percentage (%)
Graves' disease	Increased flow	10	90.9
Hashimoto's thyroiditis	Decreased/patchy flow	16	72.7

Table 6 compares vascularity patterns. Graves' disease showed increased intraglandular vascularity (thyroid inferno), while Hashimoto's showed variable or reduced flow.

Table 7: Distribution of Thyroid Nodules (Cytologically Evaluated)

FNAC Result	Frequency	Percentage (%)
Benign	28	66.7
Indeterminate (AUS)	10	23.8
Malignant	4	9.5

Table 7 reveals the cytological outcome of nodular thyroid lesions. Most nodules were benign (66.7%).

Table 8: Elastography Scoring of Thyroid Nodules

Elastography Score	Cytology Outcome	Frequency	Percentage (%)
Score 1–2	Benign	24	85.7
Score 3	Indeterminate	8	80.0
Score \geq 4	Malignant	4	100.0

Table 8 shows elastography findings. Most benign nodules scored 1–2, while malignant lesions scored \geq 4.

Table 9: Doppler Vascularity in Thyroid Nodules

Vascularity Pattern	Cytology Outcome	Frequency	Percentage (%)
Peripheral only	Benign	18	64.3
Intranodular	Malignant	3	75.0
Mixed	Indeterminate	6	60.0
Avascular	Benign	6	21.4

Table 9 evaluates nodule flow patterns. Malignant nodules predominantly showed intranodular flow, while benign nodules exhibited peripheral or no flow.

Table 10: Diagnostic Performance of Multiparametric USG (Nodules Only)

Parameter	Value (%)
Sensitivity	100.0
Specificity	89.7
Positive Predictive Value	57.1
Negative Predictive Value	100.0
Diagnostic Accuracy	91.4

Table 10 presents the sensitivity, specificity, PPV, NPV, and overall accuracy of multiparametric USG

Table 1 showed that the highest number of patients were in the 31–45 years age group. Table 2 confirmed a strong female predominance. Table 3 revealed neck swelling as the most common presenting complaint. Table 4 outlined the distribution of diffuse and nodular thyroid pathologies, with nodular lesions being slightly more frequent. Table 5 demonstrated that Hashimoto's thyroiditis had coarse, heterogeneous echotexture, while Graves' disease showed hypoechoic texture. Table 6 indicated that Graves' disease had increased intraglandular flow, in contrast to Hashimoto's with reduced or patchy flow. Table 7 showed that most thyroid nodules were benign, while a small fraction were malignant. Table 8 confirmed that higher elastography scores correlated with malignancy. Table 9 highlighted that malignant nodules predominantly had intranodular or mixed vascularity. Table 10 illustrated that multiparametric ultrasonography had excellent sensitivity and diagnostic accuracy in distinguishing malignant from benign nodules.

Discussion

The evaluation of thyroid parenchymal diseases poses a unique diagnostic challenge, as clinical findings alone are often insufficient to distinguish between benign and malignant pathology. The present study was undertaken to assess the role of multiparametric ultrasonography in characterizing both diffuse and nodular thyroid diseases, integrating gray-scale imaging, Doppler flow analysis, and elastography for a holistic diagnostic approach [10,11].

In this study, females constituted the majority of the sample, which aligns with the well-documented higher prevalence of thyroid disorders in women, often attributed to hormonal influences and autoimmune predisposition. Most patients presented in the 31–45 years age group, consistent with the age range during which thyroid dysfunction typically manifests clinically [12].

Diffuse thyroid diseases formed a significant proportion of cases, primarily Hashimoto's thyroiditis and Graves' disease. Gray-scale imaging revealed characteristic appearances: Hashimoto's thyroiditis presented with coarse, heterogeneous echotexture due to chronic autoimmune infiltration, while Graves' disease was noted for its hypoechoic yet uniform gland architecture [13]. Doppler imaging provided crucial differentiation; Graves' disease demonstrated markedly increased vascularity ("thyroid inferno"), while Hashimoto's showed variable or diminished flow in later stages. These findings corroborate prior studies emphasizing the diagnostic value of vascular

in predicting malignancy among nodular thyroid lesions.

patterns in autoimmune thyroid disease differentiation [14].

Nodular thyroid disease was slightly more prevalent in our study and was subjected to detailed multiparametric assessment. The majority of nodules were cytologically benign. Key gray-scale features such as solid composition, hypoechogenicity, irregular margins, and microcalcifications have long been associated with higher malignancy risk. However, these features can overlap with benign conditions, making adjunctive imaging tools necessary [15].

Elastography added substantial value in this context. Malignant nodules exhibited higher stiffness scores (≥ 4), consistent with the increased cellularity and desmoplastic reaction often seen in thyroid cancers. All malignant nodules in this study fell within the high elastography score range, reaffirming the utility of this technique. Moreover, elastography demonstrated excellent negative predictive value, potentially reducing the need for unnecessary biopsies in low-suspicion nodules [16].

Doppler flow patterns also provided useful insights in nodular evaluation. Intranodular vascularity was more frequent in malignant lesions, while benign nodules often showed peripheral or absent vascular flow. Although Doppler alone is not definitive, it enhances suspicion when correlated with morphological and elastographic findings [17].

Multiparametric USG in this study achieved a diagnostic accuracy of 91.4% for detecting malignancy in thyroid nodules, with 100% sensitivity and high specificity. These results are in agreement with existing literature that supports the integration of multiparametric modalities to enhance diagnostic precision, reduce indeterminate outcomes, and improve patient triaging for FNAC [18].

One of the key strengths of this study was the combined analysis of both diffuse and nodular thyroid diseases using a non-invasive, real-time approach. The study also demonstrated the practical feasibility of applying elastography and Doppler in routine thyroid imaging. However, limitations include the relatively small number of malignant cases, lack of long-term follow-up, and non-utilization of CEUS due to technical and cost constraints.

Future studies with larger sample sizes, inclusion of contrast-enhanced ultrasonography, and follow-up data could further refine imaging criteria for malignancy prediction and provide guidelines for risk stratification protocols.

Conclusion

Multiparametric ultrasonography has emerged as a valuable, non-invasive diagnostic tool for the evaluation of parenchymal thyroid diseases. By combining gray-scale imaging, color Doppler assessment, and elastography, this approach offers a comprehensive evaluation of both diffuse and nodular thyroid pathologies. The integration of elastography significantly enhances the ability to distinguish between benign and malignant nodules, while Doppler imaging aids in identifying characteristic vascular patterns in autoimmune thyroid disorders. This study confirms that multiparametric USG achieves high diagnostic accuracy, sensitivity, and negative predictive value, making it an effective frontline modality. Its routine application in clinical practice may reduce unnecessary FNACs and improve early and accurate diagnosis, thereby facilitating timely management and better patient outcomes.

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