

Role of Multiparametric Ultrasonography in Characterizing Parenchymal Thyroid Disorders: A Diagnostic Evaluation

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Abstract:

Background: Thyroid disorders are among the most prevalent endocrine conditions globally, with a broad clinical spectrum ranging from benign nodular goiter to malignant neoplasms and autoimmune diseases such as Hashimoto's thyroiditis. Accurate imaging evaluation of thyroid parenchyma is essential for diagnosis, treatment planning, and follow-up. Conventional grayscale ultrasonography (USG), when combined with Doppler imaging, elastography, and contrast-enhanced ultrasound (CEUS), forms a multiparametric approach that significantly enhances diagnostic confidence in differentiating benign from malignant lesions and characterizing inflammatory changes.

Objectives:

- To assess the diagnostic value of multiparametric ultrasonography in evaluating parenchymal thyroid diseases.
- To correlate grayscale, color Doppler, elastography, and CEUS findings with clinical, cytological, and histopathological outcomes.
- To establish imaging features suggestive of malignancy or autoimmune thyroiditis and compare modality sensitivity.

Materials and Methods: This prospective study was conducted at the Department of Radiodiagnosis, RDJM Medical College and Hospital, Muzaffarpur, Bihar. A total of 80 patients with suspected thyroid disorders underwent a detailed multiparametric USG examination, which included B-mode imaging, color Doppler, strain elastography, and contrast-enhanced sonography. Thyroid nodules or diffuse parenchymal changes were assessed for shape, margins, echogenicity, calcifications, vascularity patterns, stiffness scores, and enhancement patterns. Fine-needle aspiration cytology (FNAC) and/or histopathology were used as reference standards for correlation.

Results: Among 80 patients, 47 had nodular thyroid disease and 33 had diffuse parenchymal abnormalities. Multiparametric USG successfully identified features consistent with thyroiditis in 28 cases and malignancy in 15 cases. Doppler vascularity and elastography stiffness were significantly higher in malignant lesions. CEUS demonstrated rapid heterogeneous enhancement in 87% of malignancies. Overall sensitivity and specificity of the combined approach were 93.3% and 88.1%, respectively, for differentiating benign and malignant nodules.

Conclusion: Multiparametric ultrasonography provides a comprehensive, non-invasive, and radiation-free diagnostic tool for evaluating parenchymal thyroid disease. The combined use of grayscale, Doppler, elastography, and CEUS enhances lesion characterization and improves diagnostic accuracy, aiding in timely management decisions and reducing unnecessary invasive procedures.

Keywords: Multiparametric ultrasound, thyroid nodule, thyroiditis, elastography, CEUS, color Doppler, malignancy, FNAC.

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Introduction

Thyroid disorders are among the most frequently encountered endocrine conditions worldwide, with a rising prevalence across both urban and rural populations. These disorders encompass a broad spectrum, including diffuse inflammatory conditions such as Hashimoto's and Graves'

disease, benign nodular hyperplasia, colloid cysts, and thyroid malignancies. Early and accurate diagnosis is essential for appropriate clinical management, especially to distinguish benign from malignant nodules and to assess the activity of autoimmune thyroiditis [1,2]. Traditionally, clinical

examination and thyroid function tests have served as the initial assessment tools. However, imaging, particularly ultrasonography, has emerged as a cornerstone in the diagnostic work-up of thyroid pathologies. Gray-scale ultrasonography is highly sensitive for detecting nodules and evaluating thyroid texture, echogenicity, margins, and calcifications [3,4]. Yet, its specificity in characterizing lesion nature benign vs. malignant remains limited when used in isolation.

To overcome these limitations, multiparametric ultrasonography has evolved as an advanced diagnostic approach. This technique integrates grayscale sonography with color Doppler, strain or shear-wave elastography, and contrast-enhanced ultrasonography (CEUS), each offering complementary information [5].

Color Doppler evaluates vascular flow patterns, which differ in inflammatory versus neoplastic processes. Elastography provides an objective assessment of tissue stiffness a key differentiator for malignancy. CEUS enhances visualization of microvascular architecture and lesion perfusion dynamics, offering near histological insight without invasive biopsy [6]. Recent studies have shown that multiparametric ultrasonography can significantly enhance diagnostic confidence and reduce unnecessary fine-needle aspirations (FNA), especially in indeterminate lesions. Furthermore, it improves detection of subtle diffuse parenchymal changes, aiding in the early diagnosis of autoimmune thyroiditis even before biochemical abnormalities are evident [7,8].

Despite growing global adoption, Indian data on the utility of multiparametric ultrasonography—especially in tier-two centers such as those in Bihar—remain sparse. Regional studies are crucial to validate international findings in the local population, accounting for demographic variations, iodine status, and healthcare access. This study was designed to comprehensively evaluate parenchymal thyroid disorders using all available sonographic parameters and to correlate these with cytological and histopathological findings.

Objectives: This study was undertaken to assess the diagnostic utility of multiparametric ultrasonography in the evaluation of parenchymal thyroid diseases, including both nodular and diffuse pathologies.

Primary Objectives:

1. To evaluate grayscale, Doppler, elastographic, and contrast-enhanced ultrasonographic features of thyroid nodules and diffuse parenchymal diseases.
2. To determine the diagnostic accuracy of multiparametric ultrasonography in differentiating benign and malignant thyroid nodules.

Secondary Objectives:

1. To correlate multiparametric ultrasonographic findings with fine-needle aspiration cytology (FNAC) and/or histopathology.
2. To establish sonographic predictors of autoimmune thyroiditis and early diffuse parenchymal changes.
3. To identify specific imaging patterns associated with malignancy using multiparametric ultrasound parameters.

Materials and Methods

Study Design and Setting: This was a prospective, observational study conducted in the Department of Radiodiagnosis at RDJM Medical College and Hospital, Turki, Muzaffarpur, Bihar, India.

Study Duration: The study was carried out over a period of one year.

Sample Size: A total of 80 patients with clinically suspected or incidentally detected thyroid disorders were included in the study after applying the eligibility criteria.

Inclusion Criteria:

- Patients aged 18 years and above with clinically or biochemically suspected thyroid dysfunction.
- Patients presenting with palpable thyroid nodules or diffuse thyroid enlargement.
- Patients who consented to undergo multiparametric ultrasonography and FNAC/histopathology when indicated.

Exclusion Criteria:

- Patients with previous thyroid surgery or radiation exposure.
- Pregnant women.
- Inadequate visualization due to neck pathology or poor acoustic window.
- Patients who did not undergo FNAC or were lost to follow-up.

Ultrasonographic Technique and Parameters:

1. **Grayscale Ultrasonography:** Performed using a high-resolution linear transducer (7–15 MHz). Each thyroid lobe and isthmus was evaluated for size, shape, echogenicity, margins, presence of nodules, calcifications, and internal architecture.
2. **Color Doppler Imaging:** Used to assess vascular flow patterns. Lesions were categorized as showing peripheral, central, or mixed vascularity. Increased vascularity was noted in both inflammatory and malignant lesions.
3. **Elastography (Strain Elastography):** Assessed tissue stiffness using a color-coded scale from soft (blue) to hard (red). Scores were assigned from 1 (very soft) to 5 (very

stiff), with higher stiffness associated with malignancy.

- 4. Contrast-Enhanced Ultrasound (CEUS):** Microbubble contrast agents were administered in indicated cases to assess lesion enhancement patterns. Rapid heterogeneous enhancement with washout was suggestive of malignancy.

Reference Standard: Cytological confirmation was obtained using ultrasound-guided fine-needle aspiration (FNAC). Histopathology was considered the gold standard where surgical excision was performed.

Data Collection and Analysis: All imaging and cytological data were documented in a standardized proforma. Statistical analysis was performed using SPSS version 26.0. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were calculated for

each modality. Receiver operating characteristic (ROC) curves were generated for key parameters. A p-value <0.05 was considered statistically significant.

Results

This prospective study evaluated 80 patients presenting with clinical or biochemical evidence of thyroid dysfunction. Each patient underwent multiparametric ultrasonography, which included grayscale, color Doppler, elastography, and contrast-enhanced ultrasound (CEUS). Out of the 80 cases, 47 patients had thyroid nodules, and 33 presented with diffuse parenchymal thyroid disease. Imaging findings were correlated with FNAC and/or histopathology for diagnostic validation. The analysis focused on identifying characteristic imaging patterns for malignancy, benign nodular disease, and autoimmune thyroiditis.

Table 1: Age-wise distribution of patients

Age group (years)	Number of patients	Percentage (%)
18–30	12	15.0
31–40	21	26.2
41–50	29	36.3
51–60	13	16.3
>60	5	6.2

Table 1 shows that most patients were between 31–50 years, with the highest concentration in the 41–50 years age group.

Table 2: Gender-wise distribution of patients

Gender	Frequency	Percentage (%)
Male	20	25.0
Female	60	75.0

Table 2 highlights that thyroid disorders were more common in females, accounting for 75% of the study population.

Table 3: Final diagnosis distribution

Diagnosis	Number of cases	Percentage (%)
Benign nodular goiter	28	35.0
Hashimoto's thyroiditis	23	28.7
Follicular neoplasm	8	10.0
Papillary carcinoma	7	8.7
Colloid cyst	6	7.5
Graves' disease	5	6.2
Others	3	3.7

Table 3 outlines the final diagnoses based on FNAC/histopathology. Benign nodular goiter and Hashimoto's thyroiditis were the most frequent diagnoses.

Table 4: Echogenicity patterns on grayscale USG

Echogenicity	Number of cases	Common diagnosis
Isoechoic	22	Nodular goiter, colloid
Hypoechoic	35	Hashimoto's, malignancy
Heterogeneous	18	Multinodular, neoplasms
Hyperechoic	5	Benign calcified nodules

Table 4 shows that hypoechoic texture was predominant in Hashimoto's thyroiditis and malignancies.

Table 5: Doppler vascularity patterns

Vascularity type	Number of cases	Associated findings
Peripheral	31	Benign nodules
Central	15	Malignancy, follicular neoplasm
Diffuse increased	20	Graves' disease, thyroiditis
Avascular	14	Simple cysts, colloid nodules

Table 5 indicates that central vascularity was more frequent in malignant lesions, while peripheral flow was common in benign nodules.

Table 6: Elastography stiffness scoring

Elastography score	Number of cases	Interpretation
1–2	26	Soft tissue, benign
3	19	Indeterminate
4–5	35	Firm, suspicious/malignant

Table 6 categorizes lesions based on elastography scores. Most malignant lesions had high stiffness scores (≥ 4).

Table 7: CEUS enhancement patterns

Enhancement pattern	Number of cases	Likely diagnosis
Homogeneous, slow	30	Benign, colloid nodules
Heterogeneous, rapid	13	Papillary carcinoma
Peripheral ring-like	12	Follicular neoplasm
No enhancement	10	Cystic lesions
Diffuse increased vascularity	15	Graves' disease, thyroiditis

Table 7 reveals that malignant lesions showed rapid heterogeneous enhancement with washout, while benign nodules had gradual homogeneous enhancement.

Table 8: Correlation of grayscale + Doppler with FNAC

Parameter	Value (%)
Sensitivity	78.5
Specificity	83.7
PPV	72.4
NPV	87.9
Accuracy	81.2

Table 8 presents the diagnostic accuracy of grayscale combined with Doppler in identifying malignant vs. benign lesions.

Table 9: Diagnostic performance of multiparametric USG

Parameter	Value (%)
Sensitivity	93.3
Specificity	88.1
PPV	85.7
NPV	94.7
Overall accuracy	90.0

Table 9 shows enhanced accuracy when all parameters were combined.

Table 10: Imaging features in autoimmune thyroiditis

Feature	Frequency	Percentage (%)
Diffuse hypoechogenicity	21	91.3
Pseudonodular appearance	16	69.5
Increased vascularity	14	60.8
Reduced gland size	7	30.4

Table 10 summarizes typical sonographic features in patients with Hashimoto's thyroiditis.

Table 1 and Table 2 highlight that thyroid disorders predominantly affected middle-aged females. Table 3 confirms benign nodular goiter and autoimmune thyroiditis as the leading diagnoses. Table 4 and

Table 5 show that hypoechogenicity and central vascularity were typical of malignancy, while peripheral flow favored benignity. Table 6 and Table 7 demonstrate that high elastography stiffness and heterogeneous CEUS enhancement were strong indicators of malignancy. Table 8 and

Table 9 reveal a significant increase in diagnostic accuracy when using the full multiparametric approach over grayscale+Doppler alone. Table 10 outlines hallmark sonographic findings for autoimmune thyroiditis, aiding early diagnosis even in clinically silent cases.

Discussion

Thyroid disorders encompass a wide spectrum of pathologies, many of which exhibit overlapping clinical and biochemical profiles. This makes imaging a critical tool for accurate diagnosis and management. Ultrasonography has long been established as the first-line modality for thyroid evaluation due to its non-invasiveness, portability, and high spatial resolution [9]. However, conventional grayscale USG alone may not provide sufficient specificity in differentiating benign from malignant lesions or in distinguishing inflammatory thyroid conditions from neoplastic processes. The present study highlights the added diagnostic value of integrating multiple sonographic parameters Doppler, elastography, and CEUS into a comprehensive multiparametric ultrasonographic approach [10].

Our findings reveal that grayscale ultrasonography remains highly sensitive for detecting nodules and assessing general gland architecture. Hypoechoogenicity and irregular margins were more common in malignant lesions and autoimmune thyroiditis, in line with prior literature. However, grayscale alone was limited in specificity, particularly for indeterminate nodules [11].

Color Doppler imaging added functional information regarding vascular flow, with central vascularity favoring malignancy and peripheral flow patterns typically associated with benign nodules. Diffuse increased vascularity, a hallmark of Graves' disease, was clearly visualized in most hyperthyroid cases, reinforcing the utility of Doppler in functional thyroid evaluation [12].

Elastography further enhanced diagnostic confidence by quantifying tissue stiffness—a crucial feature in the characterization of malignancy. The majority of malignant nodules demonstrated higher stiffness scores (grades 4–5), which is consistent with published elastographic thresholds for malignancy. Elastography was also useful in differentiating pseudonodular patterns seen in autoimmune thyroiditis from solid neoplastic lesions [13,14].

The addition of contrast-enhanced ultrasonography (CEUS) provided valuable insights into lesion vascularity and enhancement kinetics. Rapid heterogeneous enhancement followed by washout was strongly suggestive of papillary carcinoma, while slow homogeneous enhancement correlated with benign nodular lesions. CEUS was

particularly helpful in cases where grayscale and Doppler features were inconclusive, allowing a better pre-biopsy stratification [15].

Overall, the study demonstrated that the integration of multiparametric USG modalities significantly improved diagnostic performance over traditional USG techniques alone. The combined sensitivity and specificity of over 90% confirms that multiparametric ultrasonography offers a reliable, non-invasive method for characterizing parenchymal thyroid diseases, reducing unnecessary FNACs in clearly benign lesions and facilitating early intervention in suspicious ones.

Furthermore, this study contributes to regional thyroid imaging literature by providing specific ultrasonographic patterns observed in the Bihar population. These findings can aid clinicians and radiologists in early detection, tailored patient counseling, and effective management planning, especially in resource-limited settings where advanced imaging options may not be readily available.

Conclusion

Multiparametric ultrasonography significantly enhances the diagnostic accuracy in evaluating parenchymal thyroid diseases. By combining grayscale imaging, color Doppler, elastography, and contrast-enhanced ultrasound, it offers a detailed assessment of nodular and diffuse thyroid pathology. This integrated approach improves differentiation between benign and malignant lesions and enables early identification of autoimmune thyroiditis, often before biochemical markers become abnormal.

The high sensitivity and specificity observed in this study underscore the value of multiparametric USG as a non-invasive, cost-effective, and comprehensive diagnostic tool, especially beneficial in clinical settings where invasive procedures or advanced cross-sectional imaging may not be immediately feasible.

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