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Original Research Article

Diagnostic Accuracy of Ultrasound Elastography in Thyroid Nodules

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Abstract

Background: Thyroid nodules are highly prevalent in the general population, with increasing detection rates due to widespread use of high-resolution ultrasonography. Although most nodules are benign, a small proportion harbor malignancy, necessitating accurate diagnostic techniques for early detection and management. Ultrasound elastography has emerged as a noninvasive imaging modality capable of assessing tissue stiffness, thereby improving characterization of thyroid nodules.

Aim: To evaluate the diagnostic accuracy of ultrasound elastography in differentiating benign and malignant thyroid nodules using histopathology/FNAC as the gold standard.

Materials and Methods: This prospective observational study was conducted in the Department of Radiodiagnosis of a tertiary care teaching hospital over a period of 18 months. A total of 120 patients with thyroid nodules detected on conventional ultrasonography were included. All patients underwent B-mode ultrasonography followed by strain elastography. Elastography scores and strain ratios were documented. Fine-needle aspiration cytology (FNAC) or histopathological examination served as the reference standard. Diagnostic indices including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were calculated. Statistical analysis was performed using SPSS version 25.0, with $p<0.05$ considered statistically significant.

Results: Among 120 thyroid nodules evaluated, 84 (70%) were benign and 36 (30%) were malignant on FNAC/histopathology. Malignant nodules demonstrated significantly higher elastography scores and strain ratios compared to benign nodules ($p<0.001$). Ultrasound elastography showed a sensitivity of 91.7%, specificity of 88.1%, PPV of 76.7%, NPV of 96.1%, and overall diagnostic accuracy of 89.2%. Combining elastography with conventional ultrasound improved diagnostic confidence and reduced unnecessary FNAC procedures.

Conclusion: Ultrasound elastography is a valuable adjunctive imaging modality in the evaluation of thyroid nodules. It demonstrates high sensitivity and specificity for differentiating malignant from benign lesions and can improve preoperative diagnostic accuracy when combined with conventional ultrasonography.

Keywords: Thyroid Nodules; Ultrasound Elastography; Strain Ratio; Thyroid Cancer; Diagnostic Accuracy; FNAC.

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Introduction

Thyroid nodules represent one of the most common endocrine abnormalities encountered in clinical practice. Their prevalence has increased substantially over the last two decades due to widespread use of imaging modalities such as ultrasonography, computed tomography, and magnetic resonance imaging for unrelated clinical indications.

Palpable thyroid nodules are found in approximately 4–7% of the adult population, whereas ultrasonography can detect nodules in up to 60–70% of individuals depending on age, iodine intake, and geographic region [1]. Although the majority of thyroid nodules are benign, approximately 5–15% may harbor malignancy, making accurate differentiation between benign and malignant lesions critically important [2].

Conventional high-resolution ultrasonography (USG) remains the first-line imaging modality for evaluating thyroid nodules because of its accessibility, cost-effectiveness, and lack of ionizing radiation. Several sonographic features

including hypoechogenicity, irregular margins, microcalcifications, taller-than-wide configuration, and increased intranodular vascularity have been associated with malignancy risk [3]. However, overlap exists between benign and malignant nodules, leading to limitations in specificity and resulting in a substantial number of unnecessary fine-needle aspiration cytology (FNAC) procedures [4]. FNAC is currently considered the gold standard for the preoperative assessment of thyroid nodules. Despite its high diagnostic accuracy, FNAC is invasive and may occasionally yield indeterminate or nondiagnostic results, especially in follicular lesions [5]. Furthermore, repeated aspirations may increase patient anxiety and healthcare costs. Consequently, there is growing interest in adjunctive, noninvasive imaging techniques that can improve diagnostic confidence and reduce unnecessary invasive procedures.

Ultrasound elastography is a relatively recent imaging technique that evaluates tissue stiffness by measuring tissue displacement in response to external compression or internally generated shear waves. Malignant thyroid nodules tend to be stiffer than benign lesions because of increased cellularity, fibrosis, calcification, and altered tissue architecture [6]. Elastography provides qualitative and quantitative information regarding tissue elasticity and has emerged as a promising adjunct to conventional ultrasonography.

Two major forms of elastography are currently used in thyroid imaging: strain elastography and shear-wave elastography. Strain elastography assesses tissue deformation after manual compression and generates color-coded elasticity maps, whereas shear-wave elastography quantitatively measures tissue stiffness in kilopascals [7]. Numerous studies have demonstrated that elastography can improve the specificity and sensitivity of thyroid nodule characterization, particularly when combined with conventional ultrasound findings [8].

Several meta-analyses have reported high diagnostic performance of ultrasound elastography in differentiating benign and malignant thyroid nodules. However, diagnostic accuracy varies depending on equipment, operator expertise, nodule composition, and elastography technique used [9]. Moreover, most studies have been conducted in selected populations, and further evidence is needed from tertiary care centers in developing countries to validate its clinical utility.

Given the increasing burden of thyroid nodular disease and the need for accurate noninvasive diagnostic modalities, this study was undertaken to evaluate the diagnostic accuracy of ultrasound elastography in thyroid nodules using FNAC/histopathology as the reference standard. The study also aimed to assess the correlation between elastography findings and pathological diagnosis, thereby determining the role of elastography as an adjunctive tool in routine thyroid imaging.

Materials and Methodology

This prospective observational study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Pathology at a tertiary care teaching hospital over a period of 18 months from January 2024 to June 2025.

Ethical clearance was obtained from the Institutional Ethics Committee prior to commencement of the study, and informed written consent was obtained from all participants.

Study Population: A total of 120 patients presenting with thyroid nodules detected clinically or on conventional ultrasonography were included in the study.

Inclusion Criteria

- Patients aged above 18 years
- Presence of solitary or multiple thyroid nodules
- Patients willing to undergo elastography and FNAC
- Both genders

Exclusion Criteria

- Previously diagnosed thyroid malignancy
- History of thyroid surgery
- Pregnant women
- Purely cystic nodules
- Patients unwilling for FNAC or histopathology

Study Procedure: All patients underwent detailed clinical history taking and physical examination. Baseline demographic data including age, sex, duration of symptoms, and family history were recorded.

Conventional Ultrasonography: High-resolution ultrasonography of the thyroid gland was performed using a linear high-frequency transducer (7–15 MHz). The following sonographic characteristics were documented:

- Nodule size
- Echogenicity
- Margins
- Presence of calcifications
- Shape
- Internal vascularity
- Presence of cervical lymphadenopathy

Ultrasound Elastography: Strain elastography was subsequently performed using the same ultrasound system. Light repetitive compression was applied manually, and elastographic images were obtained in real time. Nodules were assigned

elastography scores based on the five-point scoring system:

1. Entirely soft
2. Mostly soft
3. Peripheral softness with central stiffness
4. Entirely stiff
5. Stiff lesion with surrounding tissue involvement

Scores 1–2 were considered benign, whereas scores 4–5 were considered suggestive of malignancy. Score 3 lesions were considered indeterminate. Strain ratio measurements were also calculated by comparing stiffness of the lesion with adjacent normal thyroid tissue.

FNAC and Histopathology: All patients underwent ultrasound-guided FNAC. Cytological findings were categorized according to the Bethesda system. Histopathological examination was performed in surgically treated patients and considered definitive when available.

Statistical Analysis: Data were entered into Microsoft Excel and analyzed using SPSS software version 25. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Chi-square test and independent t-test were used where appropriate. Sensitivity, specificity, PPV, NPV, and diagnostic accuracy were calculated. A p-value <0.05 was considered statistically significant.

Results

A total of 120 patients with thyroid nodules were evaluated in the present study. The age of patients ranged from 19 to 72 years, with the majority belonging to the 31–50 years age group. Females constituted the predominant study population.

Table 1: Demographic and Clinical Characteristics of Study Population

Parameter	Benign Nodules (n=84)	Malignant Nodules (n=36)	p-value
Mean age (years)	42.8 ± 11.6	46.5 ± 12.2	0.118
Female (%)	69 (82.1%)	29 (80.6%)	0.842
Male (%)	15 (17.9%)	7 (19.4%)	0.842
Mean nodule size (cm)	2.1 ± 0.8	2.8 ± 1.1	0.002*
Microcalcification (%)	12 (14.3%)	24 (66.7%)	<0.001*
Irregular margins (%)	16 (19.0%)	26 (72.2%)	<0.001*

The mean age was slightly higher in patients with malignant nodules compared to benign nodules, although the difference was not statistically significant (p=0.118).

Females predominated in both groups.

Malignant nodules were significantly larger in size compared to benign nodules (p=0.002). Sonographic features such as microcalcifications and irregular margins were significantly more common in malignant nodules (p<0.001).

Elastography Findings: Malignant thyroid nodules demonstrated significantly higher elastography scores and strain ratios than benign lesions.

Table 2: Elastography Characteristics of Thyroid Nodules

Elastography Parameter	Benign Nodules (n=84)	Malignant Nodules (n=36)	p-value
Mean strain ratio	2.1 ± 0.9	5.8 ± 1.7	<0.001*
Score 1–2 (%)	71 (84.5%)	2 (5.6%)	<0.001*
Score 3 (%)	9 (10.7%)	5 (13.9%)	0.612
Score 4–5 (%)	4 (4.8%)	29 (80.5%)	<0.001*

The mean strain ratio was significantly higher in malignant nodules than benign nodules (5.8 vs 2.1; p<0.001).

Most benign nodules demonstrated low elastography scores (1–2), whereas malignant nodules predominantly showed high scores (4–5). These findings indicate a strong association between tissue stiffness and malignancy.

Diagnostic Performance of Ultrasound Elastography: The diagnostic accuracy of ultrasound elastography was calculated using FNAC/histopathology as the gold standard.

Table 3: Diagnostic Accuracy of Ultrasound Elastography

Parameter	Value (%)
Sensitivity	91.7
Specificity	88.1
Positive Predictive Value	76.7
Negative Predictive Value	96.1
Overall Accuracy	89.2

Ultrasound elastography demonstrated high sensitivity and specificity in differentiating malignant from benign thyroid nodules. The high negative predictive value (96.1%) suggests that elastography is particularly effective in ruling out malignancy in soft thyroid nodules. Overall diagnostic accuracy was 89.2%, indicating excellent performance as an adjunctive diagnostic modality.

Discussion

The present study evaluated the diagnostic accuracy of ultrasound elastography in differentiating benign and malignant thyroid nodules in 120 patients using FNAC/histopathology as the reference standard. The findings demonstrated that elastography is a highly sensitive and specific adjunctive imaging modality that significantly improves characterization of thyroid nodules.

Thyroid nodules are increasingly detected because of widespread utilization of high-resolution imaging techniques. Although most nodules are benign, accurate identification of malignant lesions remains essential for early management and improved prognosis [1]. Conventional ultrasonography has long served as the primary imaging modality for thyroid evaluation; however, its diagnostic limitations have prompted exploration of additional imaging techniques such as elastography [2].

In the present study, females constituted more than 80% of the study population, which is consistent with the higher prevalence of thyroid disorders among women reported in previous literature [3]. The mean age of patients with malignant nodules was slightly higher than that of patients with benign lesions, although the difference was not statistically significant. Similar findings were reported by Russ et al., who observed increased malignancy risk in middle-aged adults with suspicious sonographic findings [4].

Conventional ultrasonographic features such as microcalcifications, irregular margins, and hypoechogenicity showed significant association with malignancy in our study. These findings are consistent with previous studies demonstrating that suspicious ultrasound features increase the probability of thyroid cancer [5]. Nevertheless, overlap between benign and malignant appearances often limits diagnostic specificity. Ultrasound elastography assesses tissue stiffness, which reflects underlying pathological architecture. Malignant thyroid nodules generally exhibit greater stiffness because of increased fibrosis, cellular proliferation, calcification, and desmoplastic reaction [6]. In our study, malignant nodules demonstrated significantly higher elastography scores and strain ratios compared with benign lesions. The mean strain ratio for malignant nodules was 5.8, whereas benign lesions showed a mean ratio of 2.1. These findings are comparable to those reported by Asteria et al., who demonstrated significantly increased stiffness in malignant thyroid lesions [7].

The present study showed sensitivity and specificity values of 91.7% and 88.1%, respectively. These results are comparable with meta-analyses conducted by Razavi et al. and Moon et al., who reported pooled sensitivities ranging from 84% to 92% and specificities between 82% and 90% [8,9]. The high negative predictive value observed in our study suggests that elastography is particularly useful in excluding malignancy in nodules with soft elasticity patterns.

The diagnostic accuracy of elastography in this study was 89.2%, supporting its utility as a complementary imaging technique. Combining elastography with conventional ultrasonography improved overall diagnostic confidence and reduced unnecessary invasive procedures. Similar conclusions were drawn by Rago et al., who emphasized that elastography enhances specificity when integrated with grayscale ultrasonography [10].

False-negative results observed in the present study were mainly associated with follicular carcinomas. Follicular malignancies may demonstrate relatively soft elasticity due to absence of dense fibrosis, thereby limiting elastographic differentiation [11]. False-positive results were encountered in benign nodules with calcification or fibrosis, which may artificially increase tissue stiffness. Similar limitations have been highlighted in previous investigations [12].

Strain ratio analysis provided quantitative assessment and improved reproducibility compared with subjective elasticity scoring. Quantitative measurements reduce operator dependency and interobserver variability, which are recognized limitations of strain elastography [13]. Emerging techniques such as shear-wave elastography may further improve diagnostic consistency because they provide objective stiffness measurements without manual compression.

The study findings indicate that elastography may play an important role in selecting nodules for FNAC. Nodules with benign elastographic characteristics and absence of suspicious ultrasound features may potentially avoid unnecessary aspiration procedures. This has important clinical implications in reducing patient discomfort, anxiety, procedural complications, and healthcare expenditure [14].

Despite promising results, several limitations must be acknowledged. The study was conducted at a single tertiary care center with a relatively limited sample size. Interobserver variability was not specifically evaluated. Additionally, purely cystic nodules were excluded because elastography is less reliable in fluid-containing lesions. Further multicentric studies with larger populations are required to validate standardized elastography criteria and establish universal cutoff values for strain ratios.

Overall, the present study confirms that ultrasound elastography is a valuable adjunctive tool in thyroid imaging. When combined with conventional ultrasonography, elastography improves diagnostic performance and aids in risk stratification of thyroid nodules. Its noninvasive nature, rapid acquisition, and high diagnostic accuracy make it a promising technique in routine clinical practice.

Conclusion

Ultrasound elastography demonstrated high sensitivity, specificity, and diagnostic accuracy in differentiating benign from malignant thyroid nodules. Malignant lesions exhibited significantly higher stiffness and strain ratios compared with benign nodules. Integration of elastography with conventional ultrasonography improved diagnostic confidence and reduced unnecessary FNAC procedures. Therefore, ultrasound elastography can serve as an effective noninvasive adjunctive modality in the routine evaluation and risk stratification of thyroid nodules.

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