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Original Article

Advances in imaging techniques for thyroid disease: ultrasound, elastography, and beyond – A prospective observational cross-sectional study.

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Abstract

Background

Accurate differentiation of benign and malignant thyroid nodules is essential for appropriate management and early detection of thyroid cancer. While ultrasonography (USG) is the primary imaging modality for thyroid evaluation, its specificity is limited by overlapping features between benign and malignant lesions. Elastography and other advanced imaging techniques have emerged as valuable adjuncts to improve diagnostic accuracy.

Methods

This prospective observational cross-sectional study included 110 adult patients with suspected thyroid disease over 11 months. All participants underwent conventional ultrasonography and elastography, while selected cases received advanced imaging, including contrast-enhanced ultrasonography and Doppler vascularity assessment. Imaging findings were correlated with fine-needle aspiration cytology (FNAC) and histopathological examination. Diagnostic performance was assessed using sensitivity, specificity, accuracy, and Chi-square testing, with $p<0.05$ considered statistically significant.

Results

Among the 110 patients, 78 (70.9%) had benign lesions, and 32 (29.1%) had malignant lesions. Ultrasonography demonstrated a sensitivity of 85.2%, specificity of 72.5%, and accuracy of 78.9%. Elastography showed superior performance with a sensitivity of 90.6%, specificity of 84.3%, and accuracy of 87.3%. The combined use of ultrasonography and elastography achieved the highest diagnostic accuracy (90.9%) and showed a statistically significant improvement compared with individual modalities ($p=0.008$). Elastography scores of 4–5 were significantly associated with malignancy ($p=0.001$). Hypoechogenicity, microcalcifications, and irregular margins were also significantly associated with malignant lesions.

Conclusion

Elastography significantly enhances the diagnostic performance of conventional ultrasonography. A multimodal imaging approach improves diagnostic accuracy and may reduce unnecessary invasive procedures.

Recommendation

Routine incorporation of elastography alongside conventional ultrasonography is recommended for comprehensive evaluation of thyroid nodules and improved early detection of thyroid malignancy.

Keywords: *Thyroid nodules, ultrasonography, elastography, diagnostic imaging, thyroid cancer, FNAC.*
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Introduction

Thyroid nodules are becoming increasingly identified in clinical settings owing to the prevalent utilisation of imaging modalities. The prevalence of thyroid nodules in the general population varies from 20% to 70%, contingent upon the diagnostic method employed, with ultrasound identifying the greatest frequencies. While most of these nodules are benign, around 5–15% may contain cancer, requiring precise and timely detection (1). Ultrasound (USG) is the primary imaging technique for assessing thyroid nodules due to its accessibility, cost-efficiency, and high sensitivity. It offers comprehensive information about nodule attributes like echogenicity, margins, calcifications, and vascularity. (2).

Nonetheless, its specificity is constrained by the overlapping characteristics of benign and malignant lesions. Elastography has become a significant complement to traditional ultrasound by evaluating tissue stiffness, a metric closely linked to malignancy. Malignant nodules are generally more rigid than benign nodules, facilitating enhanced distinction. Methods like strain elastography and shear-wave elastography have demonstrated encouraging outcomes in improving diagnostic precision. (3).

Moreover, sophisticated imaging techniques, such as contrast-enhanced ultrasonography and Doppler investigations, are being progressively investigated to boost diagnostic precision, especially in ambiguous circumstances. This study is to assess the diagnostic efficacy of ultrasound, elastography, and advanced imaging modalities in thyroid disorders, and to ascertain whether a synergistic imaging strategy enhances accuracy relative to traditional methods alone(4).

Methods

Study Design

This prospective observational cross-sectional study was conducted over a period of 11 months (January 26 to March-25) among patients presenting with suspected thyroid disease. The study aimed to evaluate the diagnostic performance of ultrasonography, elastography, and advanced imaging modalities in differentiating benign and malignant thyroid lesions.

Study Setting

This study was Multicentric conducted in the Department of Otorhinolaryngology in collaboration with the Department of Radiodiagnosis and Pathology at Multicentric study in tertiary care teaching hospital located in Uttar Pradesh, India. Data Collection between January 26 to March-25.

Sample Size Determination

A total of 110 patients were enrolled during the study period. The sample size was determined using consecutive sampling of all eligible patients presenting during the study duration who fulfilled the inclusion criteria and provided informed consent.

Study Population

Adult patients aged more than 18 years presenting with thyroid nodules or diffuse thyroid enlargement and referred for imaging evaluation were considered eligible for inclusion.

Inclusion Criteria

Patients aged more than 18 years with clinically or radiologically suspected thyroid nodules or diffuse thyroid enlargement, and willing to participate in the study, were included.

Exclusion Criteria

Patients with a history of previous thyroid surgery, incomplete imaging evaluation, incomplete cytological or histopathological records, or those unwilling to participate were excluded from the study.

Imaging Assessment

All enrolled patients underwent conventional ultrasonography performed by experienced radiologists. Sonographic features, including nodule size, echogenicity, margins, calcifications, composition, and vascularity, were recorded.

Subsequently, elastography assessment was performed using strain elastography with a five-point scoring system. Shear-wave elastography measurements were additionally recorded wherever available.

Advanced imaging techniques, including contrast-enhanced ultrasonography and Doppler vascularity assessment, were performed in selected cases with indeterminate sonographic findings.

Reference Standard

Fine Needle Aspiration Cytology (FNAC) was performed for all clinically indicated lesions. Histopathological

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examination findings were considered the gold standard whenever surgical specimens were available. Imaging findings were compared with cytological and histopathological diagnoses.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using SPSS version 20 Sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy were calculated. Associations between imaging characteristics and malignancy were assessed using the Chi-square test. A p-value less than 0.05 was considered statistically significant.

Bias Minimization

To minimize observer bias, imaging examinations were performed according to standardized protocols by experienced radiologists. Cytological and histopathological assessments were conducted independently without prior knowledge of imaging findings. Consecutive patient recruitment was employed to reduce selection bias.

Results

During the study period, 128 patients were assessed for eligibility. Twelve patients were excluded due to incomplete imaging records, and six patients declined participation. A total of 110 patients fulfilled the eligibility criteria and were included in the final analysis.

Patient Distribution

- Total: 110 patients
- Benign: 78 (70.9%)
- Malignant: 32 (29.1%)

Table 1 demonstrates that combined imaging achieved the highest diagnostic accuracy (90.9%), followed by elastography (87.3%) and ultrasonography (78.9%). The improvement in diagnostic performance observed with combined imaging was statistically significant.

Table 1: Diagnostic Performance of Imaging Modalities

Modality	Sensitivity (%)	Specificity (%)	Accuracy (%)	p-value
Ultrasound	85.2	72.5	78.9	0.041
Elastography	90.6	84.3	87.3	0.012
Combined	93.7	88.1	90.9	0.008

Higher elastography scores were significantly associated with malignant lesions. Most benign lesions demonstrated elastography scores of 1–2, whereas malignant lesions predominantly exhibited scores of 4–5

Table 2: Elastography Score vs Malignancy

Elastography Score	Benign (n=78)	Malignant (n=32)	p-value
1–2	52	3	
3	18	7	
4–5	8	22	0.001

Hypoechogenicity, microcalcifications, and irregular margins were significantly more common among malignant lesions compared with benign lesions, indicating their importance as sonographic predictors of malignancy.

Table 3: Ultrasound Features Associated with Malignancy

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Feature	Benign (%)	Malignant (%)	p-value
Hypoechogenicity	30	75	0.002
Microcalcifications	12	68	0.001
Irregular margins	18	72	0.003

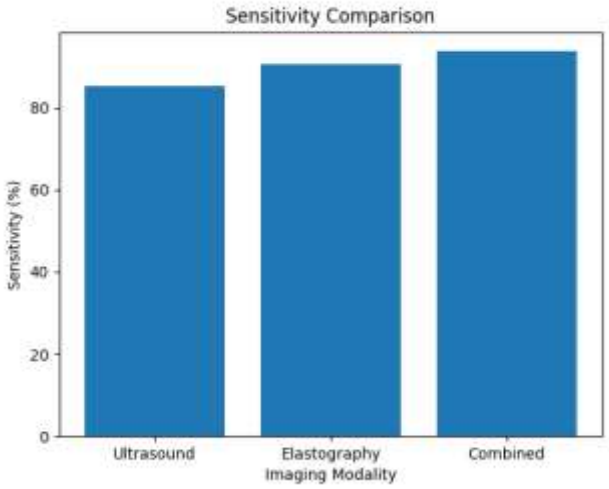

Figure 1: Sensitivity comparison

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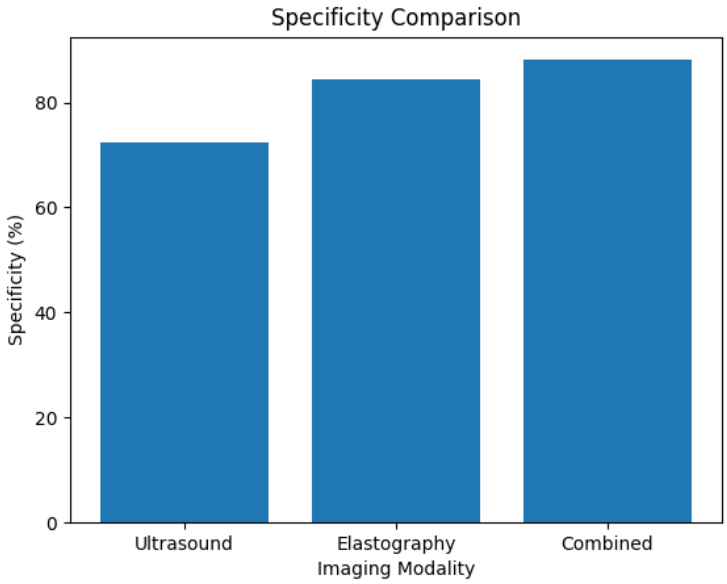

Figure 2: Specificity comparison

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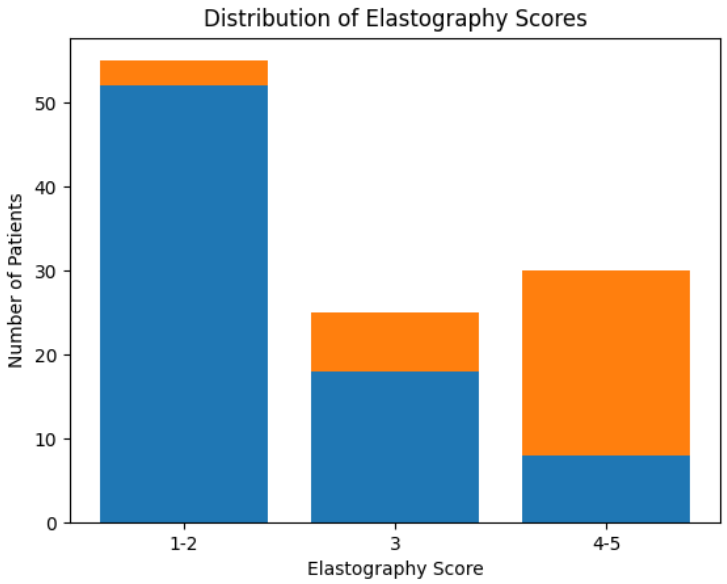

Figure 3: distribution of elastography scores

Discussion

The current study emphasises the growing relevance of advanced imaging tools in the assessment of thyroid disease. Ultrasound, while very sensitive, had insufficient specificity in distinguishing between benign and malignant nodules. This limitation has been extensively established, and it is mostly caused by overlapping sonographic characteristics such as hypoechogenicity and uneven borders in both benign and malignant lesions.

Elastography dramatically enhanced diagnostic performance by providing more information about tissue stiffness. In this investigation, elastography demonstrated better sensitivity (90.6%) and specificity (84.3%) than ultrasonography alone, with statistically significant results ($p = 0.012$)(5). Notably, higher elastography values (4-5) were significantly linked with malignancy, highlighting the need for stiffness measurement in clinical practice. (4).

The combination of ultrasound and elastography produced the highest diagnosis accuracy (90.9%), highlighting the value of a multimodal approach. This combination enables clinicians to incorporate morphological and functional information, increasing diagnostic confidence and avoiding needless biopsies. (6), (3).

Advanced imaging techniques, such as contrast-enhanced ultrasonography and Doppler studies, also helped in certain situations, particularly in nodules with indeterminate features on conventional imaging. (7). These techniques aid in determining vascular patterns and perfusion features, which may provide additional hints to malignancy. (8).

The findings of this study are consistent with earlier research that supports the incorporation of elastography into standard thyroid imaging methods. However, there are certain drawbacks, such as operator dependency in elastography and scoring system unpredictability. (9).

Overall, this study emphasises that, while ultrasonography is still necessary, adjunct techniques such as elastography greatly improve diagnostic accuracy(10). Future technologies, such as artificial intelligence and quantitative imaging, may improve thyroid nodule detection. (11).

Generalizability

Despite these limitations, the findings apply to similar tertiary care settings where ultrasonography and elastography are routinely available. The results support the integration of elastography into standard thyroid imaging

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protocols and may be generalizable to comparable patient populations undergoing evaluation for thyroid nodules.

Conclusion

Ultrasound is the dominant imaging technique for thyroid examination; nevertheless, its specificity is restricted. Elastography improves diagnostic accuracy by providing useful information on tissue stiffness, which is associated with malignancy. The combination of ultrasound and elastography provides higher sensitivity and specificity than either modality alone. Advanced imaging techniques enhance evaluation in uncertain circumstances. To best assess thyroid nodules, a multimodal imaging strategy is advised. Incorporating these approaches into ordinary clinical practice may lessen the need for invasive procedures and enhance the early diagnosis of thyroid cancer.

Limitations

The present study has several limitations. First, the sample size was relatively small and conducted at a single tertiary care centre, which may limit generalizability. Second, elastography remains partially operator dependent and may introduce interobserver variability. Third, advanced imaging techniques were performed only in selected patients rather than uniformly across the study population. Finally, long-term follow-up data were not available to assess clinical outcomes.

Recommendations

Based on the findings of this study, elastography should be incorporated alongside conventional ultrasonography for the routine evaluation of thyroid nodules whenever feasible. Future multicentric studies with larger sample sizes and incorporation of artificial intelligence-assisted imaging analysis are recommended to further enhance diagnostic accuracy and validate these findings.

Acknowledgement

The authors acknowledge all study participants and the staff of the Departments of Otorhinolaryngology, Radiodiagnosis, and Pathology for their support during data collection and analysis.

Abbreviation Full Form

USG Ultrasonography
FNAC Fine Needle Aspiration Cytology
CEUS Contrast Enhanced Ultrasonography
IEC Institutional Ethics Committee
PPV Positive Predictive Value
NPV Negative Predictive Value

Source of Funding

No external funding was received for this study.

Conflict of Interest

The authors declare that there is no conflict of interest.

Data Availability

The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

Shikhar Saxena
Conceptualization, study design, manuscript drafting.
Parul Sachan
Data collection, pathology review, and data interpretation.
Daya Shankar
Study supervision, statistical analysis, and manuscript revision.
Rohini Srivastava
Data validation, pathology correlation, and final manuscript approval.

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