



Article

Role of Ultrasound Elastography in Differentiating Benign and Malignant Thyroid Nodules

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Abstract: In clinical practice, thyroid nodules are among the most prevalent endocrine disorders: Context. Although most nodules are benign, it may be difficult to distinguish between benign and malignant nodules prior to surgery. Ultrasound elastography is a new imaging method that may be used to detect tissue stiffness and is thought to improve the effectiveness of traditional ultrasonography. This research aimed to evaluate the accuracy of using ultrasonic elastography in combination with a traditional ultrasound examination to distinguish between benign and malignant thyroid nodules. From Jan. 2024 to Jan. 2025, prospective cross-sectional research was carried out at the Tikrit Teaching Hospital in Tikrit City, Iraq. Ninety individuals with thyroid nodules of all sexes and ages ranging from 25 to 65 were included. On a high-resolution ultrasound equipment equipped with elastography software, each participant underwent the standard B-mode ultrasound, color Doppler imaging, strain elastography, and shear wave elastography procedures. Elasticity score, strain ratio, and shear wave elasticity value are examples of elastographic parameters that have been measured, analyzed, and compared with cytopathological and histopathological findings that served as the reference standard. Using SPSS 27, the data was statistically analyzed, and diagnostic performance indexes were computed. Every thyroid nodule was either cancerous (27, 30.0%) or benign (63, 70.0%). Malignant nodules had considerably greater strain ratios, elasticity scores, and shear wave elasticity values than benign nodules ($p < 0.001$). Hypoechoogenicity, uneven edges, microcalcifications, taller than broad form, and enhanced intranodular vascularity were the traditional ultrasonic characteristics linked to malignancy. Ultrasound elastography had an overall diagnostic accuracy of 91.1%, an area under the receiver operating characteristic curve of 0.951, and sensitivity, specificity, positive, and negative predictive values of 92.6%, 90.5%, 81.0%, and 96.6%, respectively. When conventional ultrasonography and elastography were used together, the total diagnosis accuracy rose to 94.4%. One practical and efficient use of ultrasound as an auxiliary imaging technique to help distinguish between benign and malignant thyroid nodules is ultrasound elastography. The combination of imaging methods is expected to increase the number of patients receiving surgical treatment, increase diagnostic accuracy, and perhaps decrease the number of needless FNA biopsies. Risk assessment and clinical decision-making may be enhanced by the regular ultrasonography examination of the thyroid using elastography.

Keywords: Thyroid nodules; Ultrasound elastography; Shear wave elastography; Strain elastography; Thyroid cancer.

1. Introduction

Due to the widespread use of high-resolution ultrasonography and innovative imaging methods, thyroid nodules one of the most frequent endocrine abnormalities seen in clinical practice have been reported to be more prevalent in recent years [1]. Only 4–7% of persons with palpable thyroid nodules are thought to benefit from radioiodine treatment, but up to 60–70% of healthy adults may have thyroid nodules detected by ultrasonography [2]. The majority of thyroid nodules are benign, while 5–15% are malignant. It is important to distinguish between benign and malignant nodules in order to treat patients appropriately and avoid needless intrusive operations [3].

The most popular imaging method for evaluating thyroid nodules is conventional ultrasonography, which is non-invasive, widely accessible, affordable, and nonradiating [4]. Color Doppler imaging has shown helpful in identifying the vascularity, whereas grayscale ultrasonography has proven helpful in assessing the size, composition, echogenicity, borders, form, and presence of calcifications [5]. The American College of Radiology Thyroid Imaging Reporting and Data System (ACR TI-RADS) is a risk stratification system designed to improve clinical decision making and standardize ultrasound interpretation. However, the sonographic features of benign and malignant nodules often overlap, particularly for ambiguous nodules, which might reduce the specificity of traditional ultrasonography [6].

In the future, ultrasound-guided fine-needle aspiration cytology (FNAC) will be used to detect any suspected thyroid nodule. Nevertheless, this is a very minimally invasive treatment that depends on the operator and may sometimes be inconclusive or non-diagnostic, necessitating a second biopsy or surgery to make a diagnosis. As a result, there is an increasing demand for additional, non-invasive imaging techniques that may improve diagnostic precision and reduce the frequency of biopsies [7, 8].

One significant advancement in thyroid imaging is the use of ultrasound elastography to measure tissue stiffness both qualitatively and quantitatively. Elastography is predicated on the idea that, due to increased cellularity, fibrosis, and altered tissue architecture, the tissue around a tumor will be stiffer than normal or non-tumorous tissue. In clinical practice, two types of elastography are used: shear wave elastography, which is based on the quantitative measurement of tissue stiffness by calculating the velocity of shear wave propagation and elasticity values (in kilopascals), and strain elastography, which is based on the estimation of tissue deformation under external compression. According to a number of studies, elastography may improve the diagnostic and characterization of thyroid nodules using traditional ultrasonography [10,11].

According to newly released international standards, elastography should be used in conjunction with traditional ultrasonography or cytopathological examination rather than as a replacement. When combined with clinical factors and grayscale ultrasound data, elastographic readings may assist improve risk assessment, diagnose patients more accurately, and identify patients who are really suspect for FNA or surgery. The many techniques used to study blood, the operators' expertise, and the various cutoff lines for the diagnosis have not been examined in other populations, despite their potential [12,13].

Because of these factors, the current study was created to evaluate the utility of ultrasound elastography in distinguishing between benign and malignant thyroid nodules, to compare this technique with traditional ultrasonography, and to validate these techniques against the reference standard of cytopathological and histopathological diagnosis.

2. Methodology

To design and set up a study

This 12-month prospective cross-sectional research with diagnostic accuracy was carried out at the radiology department of the Tikrit teaching hospital in Salah AlDin, Iraq (January 2024–January 2025). By comparing the elastographic results with the cytopathological and histopathological diagnoses as the reference standards, the research sought to evaluate the diagnostic utility of ultrasound elastography in differentiating between benign and malignant thyroid nodules. The research procedure was overseen and approved by the Tikrit University College of Medicine's ethics committee, and each participant provided informed written permission prior to study enrolment.

Study Population

Ninety consecutive individuals with one or more clinically or traditionally ultrasonographic thyroid nodules were included in the research. Patients between the ages of 25 and 65 of both sexes were included. Age, sex, BMI, length of thyroid illness, family history of thyroid cancer, smoking status, and thyroid function tests were all recorded for each participant. In patients with numerous thyroid nodules, only the most worrisome thyroid nodule on the ACR Thyroid Imaging Reporting and Data System (ACR TI-RADS) was examined in order to avoid clustering bias.

Inclusion Criteria

Patients had to be between the ages of 25 and 65, be of either sex, and have one or more thyroid nodules on B-mode ultrasonography with a maximum diameter of at least 5 mm. After that, the nodules underwent further processing for either surgical removal and histological investigation or ultrasound guided fine needle aspiration cytology (FNAC). Before taking part, each subject had to provide informed permission.

Exclusion Criteria

Thyroid cancer patients who had previously been diagnosed have undergone surgery, radioiodine treatment, chemotherapy, or neck irradiation. Individuals with pregnancy, severe coagulation disorders that prevent FNAC, diffuse thyroid diseases without distinct nodules, purely cystic nodules without any solid component, inadequate cytological samples (Bethesda category I), and poor quality elastographic samples due to excessive motion artefacts or poor cooperation during scanning were also excluded.

Clinical Evaluation

Every participant had a thorough physical examination and a complete medical history obtained. A thorough medical history and physical examination were performed on each subject. Additional clinical factors were thyroid disease symptoms, a family history of thyroid cancer, usage of thyroid medicines, and other endocrine disorders. Serum thyroid stimulating hormone (TSH), free thyroxine (FT4), free triiodothyronine (FT3), and anti-thyroid antibodies were among the laboratory tests carried out as indicated.

Ultrasound Examination

Two skilled radiologists with more than eight years of thyroid imaging expertise performed the tests; they were blind to the cytological and histological findings. Scanning was done using a high-resolution ultrasound equipment with elastography software, such as the GE LOGIQ E10 and Samsung RS85 Prestige ultrasound systems. A high frequency linear-array transducer (7–15 MHz) was used for every testing.

In order to get a clear view of the thyroid, all patients were evaluated in the supine posture with minimum neck hyperextension. Initially, each thyroid nodule was identified using ACR TI-RADS criteria and the thyroid morphology was evaluated using standard grayscale ultrasonography. Nodule size, location, composition, echogenicity, form, borders, calcification type and presence, halo sign, internal architecture, vascularity (using

colour Doppler imaging), cervical lymphadenopathy, and background thyroid parenchymal echogenicity were all recorded sonographically.

Ultrasound Elastography Assessment

In the same examination, elastography was performed after conventional ultrasonography. Shear wave elastography and strain elastography were employed wherever feasible. In strain elastography, the probe was physically pressed on the thyroid perpendicular to the thyroid while the thyroid was compressed by pushing it in the probe's direction and the ultrasound system's compression quality indicator was adjusted appropriately. The exams were conducted three times, and the elastography picture that was the most stable was examined. A five-point elasticity scoring system (ES 1–5) was used to evaluate elasticity; a lower score indicated "softer," and a higher score indicated "harder," with increasing tissue hardness that would be suggestive of cancer. Additionally, the strain ratio was automatically computed by comparing the stiffness of the thyroid nodule to either the ipsilateral sternocleidomastoid muscle or the nearby normal thyroid tissue.

Shear wave elastography, in which a standardized region of interest (ROI) was placed across the solid portion of the nodule, could not account for cystic degeneration or peripheral artefacts. For every lesion, repeated measurements were taken while the transducer was not compressed. The average elasticity value was expressed in metres per second (m/s) and kilopascals (kPa). Maximum elasticity (E_{max}), mean elasticity (E_{mean}), minimum elasticity (E_{min}), and elasticity standard deviation were additional elasticities that were computed. Three measurements were averaged and statistically evaluated.

Ultrasound-Guided Fine Needle Aspiration Cytology

Aseptic ultrasound-guided FNAC was performed with a 23 or 25 gauge needle. Expert cytopathologists who were unaware of the elastography data promptly aspirated, fixed, and assessed the samples. The Bethesda System for Reporting Thyroid Cytopathology (Bethesda Categories I–VI) was used to categorise the cytological diagnosis. According to current standards, all patients with Bethesda category III or IV nodules had surgical excisions or repeat FNAC.

Histopathological Examination

The standard histopathologic procedure was used to process the surgical specimens from the patients undergoing thyroid surgery. When available, the "gold standard" was a histopathological diagnosis. Both benign (nodular hyperplasia, colloid nodules, adenomas, Hashimoto thyroiditis) and malignant (papillary thyroid cancer, follicular carcinoma, medullary carcinoma, poorly differentiated carcinoma, and other thyroid malignancies) abnormalities were ultimately diagnosed.

Outcome Measures

The ability of ultrasound elastography to distinguish between benign and malignant thyroid nodules was the main outcome. Comparing the elasticity score of benign and malignant lesions, determining the ideal elasticity score cut-off values, and evaluating the correlation between elastographic data and the ACR TI-RADS were additional secondary goals. The comparison of the elasticity scores of benign and malignant lesions, determining the ideal cut-off value for the elasticity score, and evaluating the diagnostic utility of combining elastography and conventional ultrasonography were the remaining secondary goals.

Statistical Analysis

Software known as the Statistical Package for Social Sciences (SPSS) version 27 was used to analyze the data. The mean and standard deviations were used to display data on continuous variables, whilst frequencies and percentages were used to display data on categorical variables. The Chi-square test or Fisher's exact test were used to analyze categorical data, while the independent samples t-test or Mann-Whitney U test, depending

on the data distribution, were used to investigate continuous data. Receiver operating characteristic (ROC) curve analysis was used to determine the ideal cut-off values of the strain ratio and shear wave elasticity for the prediction of malignancy. Sensitivity, specificity, positive and negative predictive values, and total diagnostic accuracy with 95% confidence intervals were computed along with the area under the ROC curve (AUC). The independent variables for thyroid cancer were found using multivariate logistic regression analysis. A p-value of less than 0.05 was considered statistically significant.

3. Results

Distribution of Demographic Characteristics

Table 1 shows the demographic characteristics of the study population. The number of patients included was 90 with thyroid nodules. The majority of the study population were female patients (83.5%) and with a mean age of 46.3 ± 10.8 years.

Table 1. Demographic characteristics of the study population.

Variable	Value
Number of patients	90
Mean age (years)	46.3 ± 10.8
Age range	25–65
Male	28 (31.1%)
Female	62 (68.9%)
BMI	27.6 ± 4.3

Histopathological Diagnosis

Pathological diagnosis of the final FNAC and histopathology are summarized in Table 2. Most of the lesions were benign and papillary thyroid carcinoma was the most common malignant diagnosis.

Table 2. Final pathological diagnosis.

Diagnosis	n	%
Benign	63	70.0
Malignant	27	30.0



Figure 1. Ultrasound-guided fine-needle aspiration (FNAC) of a suspicious thyroid nodule using a 25-gauge needle under real-time ultrasound guidance.

Conventional Ultrasound Findings

The parameters of the grayscale and Doppler are listed in Table 3. More hypoechogenicity, irregular margins, microcalcifications, increased vascularity and taller than wide thyroid nodule shape were significantly associated with the presence of malignant nodules.

Table 3. Conventional ultrasound findings.

Finding	Benign	Malignant	P value
Hypoechogenicity	18	23	<0.001
Irregular margin	9	21	<0.001
Microcalcifications	7	18	<0.001
Solid composition	29	25	<0.001
Taller-than-wide	5	17	<0.001
Increased vascularity	16	19	<0.001



Figure 2. Longitudinal grayscale ultrasound demonstrating a benign colloid thyroid nodule with an oval shape, smooth margins, and a thin peripheral halo.



Figure 3. Transverse grayscale ultrasound image of papillary thyroid carcinoma showing a markedly hypoechoic solid nodule with irregular margins, punctate echogenic foci (microcalcifications), and a taller-than-wide configuration.

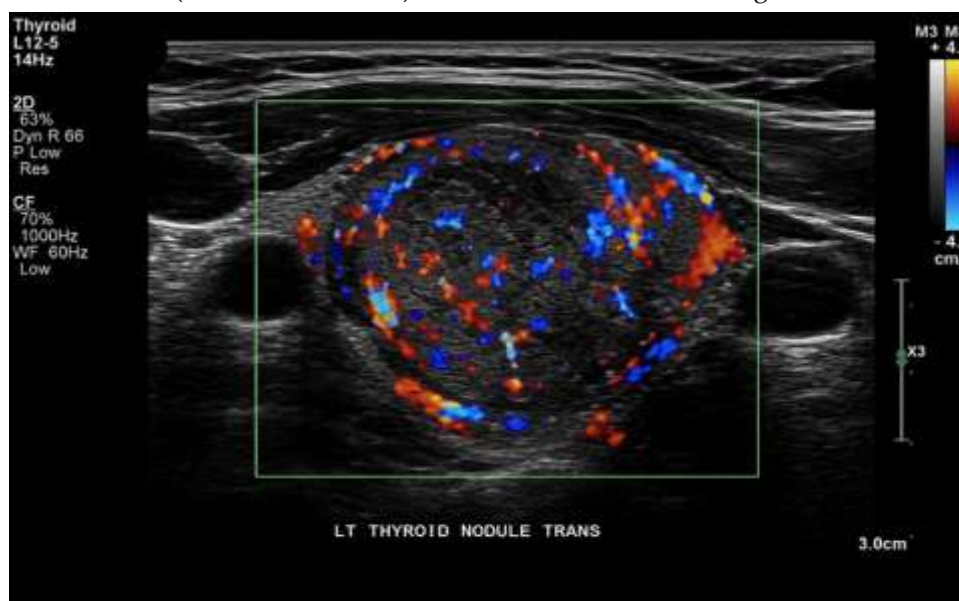


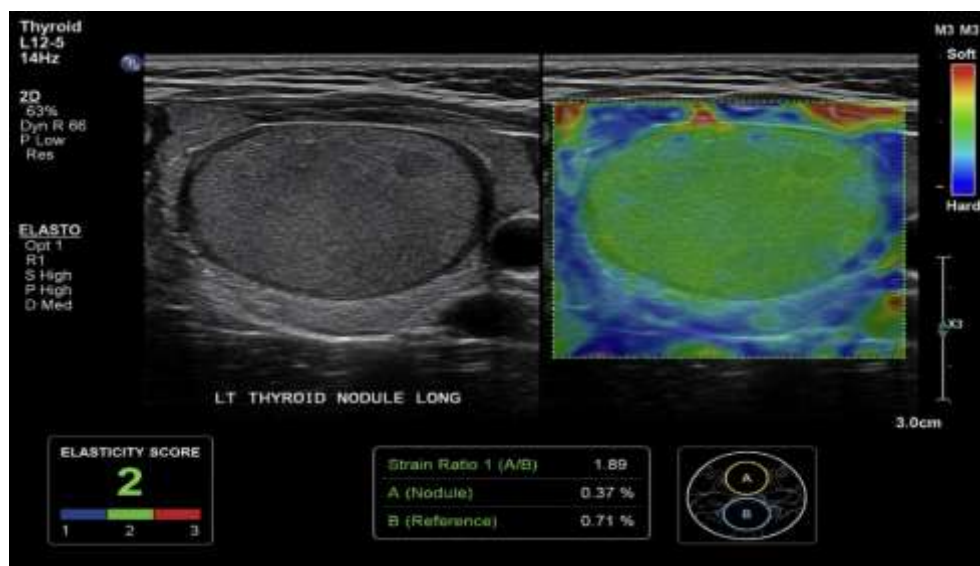
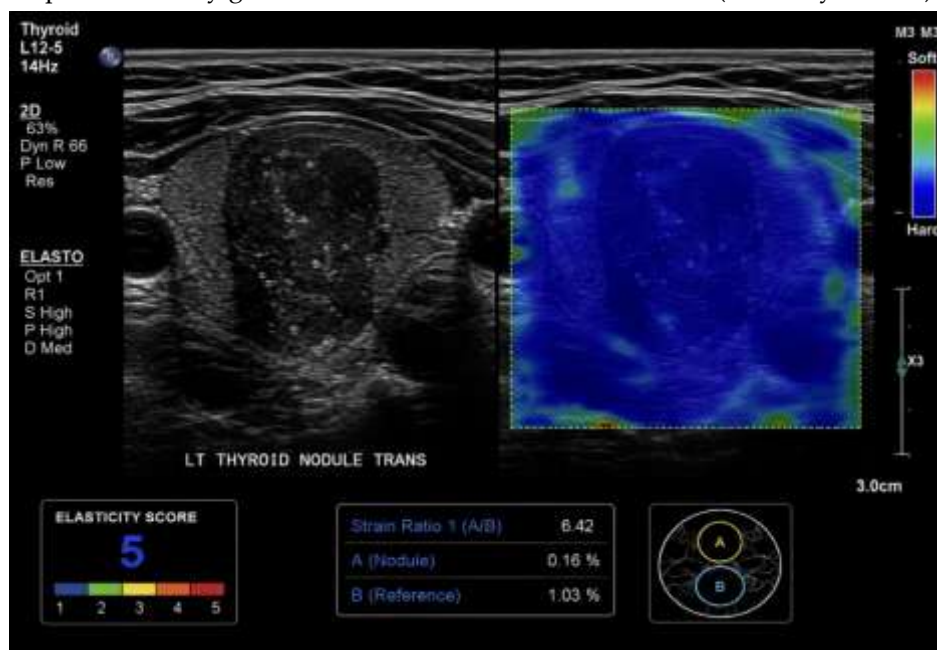
Figure 4. Color Doppler ultrasound demonstrating increased intranodular vascularity within a malignant thyroid nodule.

Ultrasound Elastography Findings

The quantifiable elastography data is shown in Table 4. All the elastographic parameters were significantly higher in the stiffness of malignant nodules than in the stiffness of benign nodules.

Table 4. Quantitative elastography measurements.

Parameter	Benign	Malignant	P value
Strain Ratio	2.14 ±0.73	5.91 ±1.48	<0.001
Mean SWE (kPa)	27.8 ±8.9	71.6 ±16.3	<0.001
Maximum SWE (kPa)	36.4 ±10.2	96.8 ±18.7	<0.001

**Figure 5.** Strain elastography of a benign thyroid nodule demonstrating predominantly green coloration with low tissue stiffness (Elasticity Score 2).**Figure 6.** Strain elastography of papillary thyroid carcinoma demonstrating diffuse blue coloration corresponding to marked tissue stiffness (Elasticity Score 5).

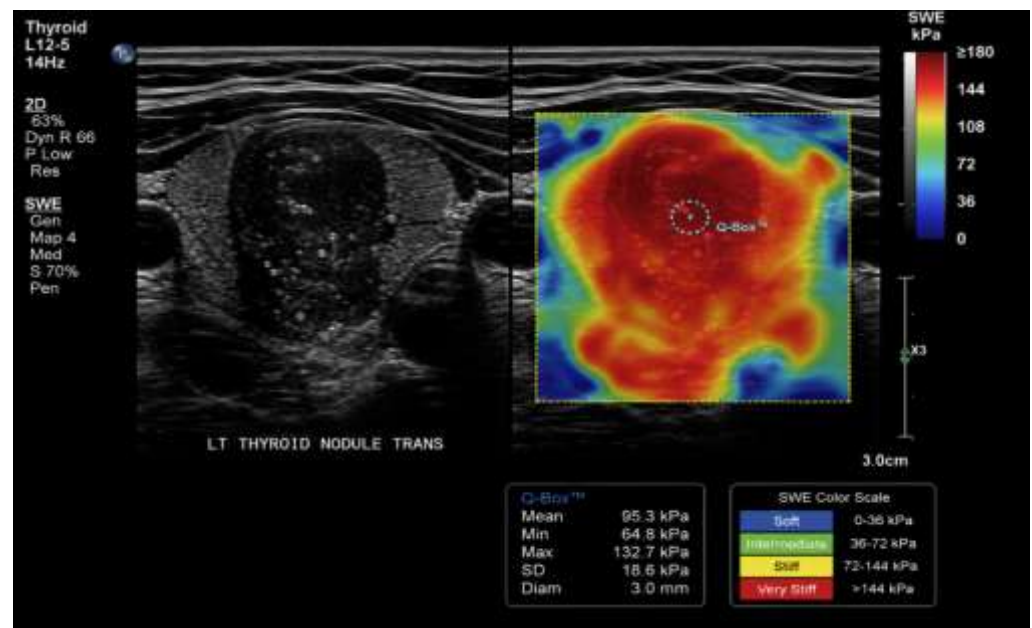


Figure 7. Shear wave elastography quantitative color map showing markedly elevated stiffness values (>80 kPa) within a malignant thyroid nodule.

Distribution of Elasticity Scores

The distribution of elasticity scores according to pathological diagnosis is shown in Table 5. Malignant thyroid nodules had the highest elasticity scores (ES 4–5).

Table 5. Distribution of elasticity scores.

Elasticity Score	Benign	Malignant
1	18	0
2	25	1
3	14	3
4	5	12
5	1	11

Diagnostic Performance of Ultrasound Elastography

The diagnostic indices of ultrasound elastography are shown in Table 6. The technique was highly sensitive, specific, and had a high diagnostic accuracy for distinguishing the benign from malignant thyroid nodules.

Table 6. Diagnostic performance of ultrasound elastography

Parameter	Value
Sensitivity	92.6%
Specificity	90.5%
PPV	81.0%
NPV	96.6%
Accuracy	91.1%
AUC	0.951

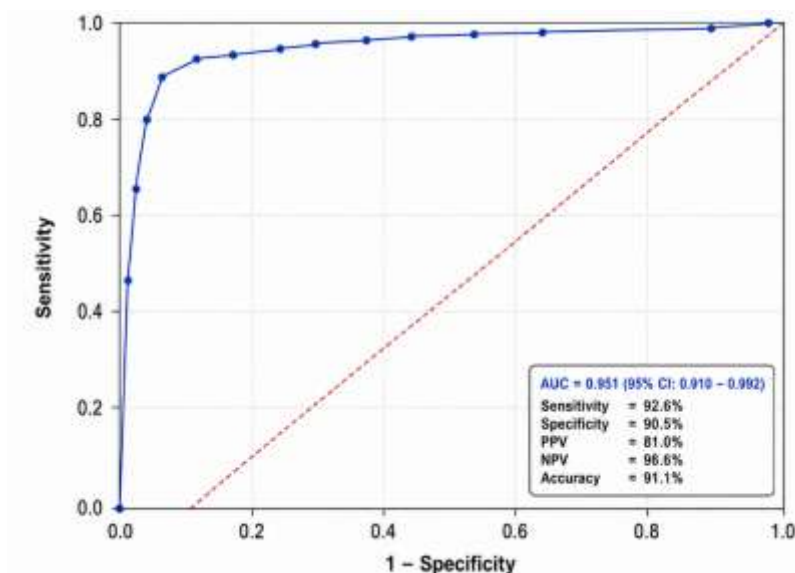


Figure 8. Receiver operating characteristic (ROC) curve demonstrating the diagnostic performance of ultrasound elastography for differentiating benign from malignant thyroid nodules (AUC = 0.951).

Comparison Between Conventional Ultrasound and Elastography

The advantages and disadvantages of conventional ultrasound as compared with elastography are listed in Table 7. The diagnostic accuracy of combination of grayscale ultrasound and elastography was significantly better than that of conventional ultrasound alone.

Table 7. Comparison of diagnostic performance.

Modality	Sensitivity	Specificity	Accuracy
Conventional ultrasound	81.5	82.5	82.2
Elastography	92.6	90.5	91.1
Combined approach	96.3	93.7	94.4

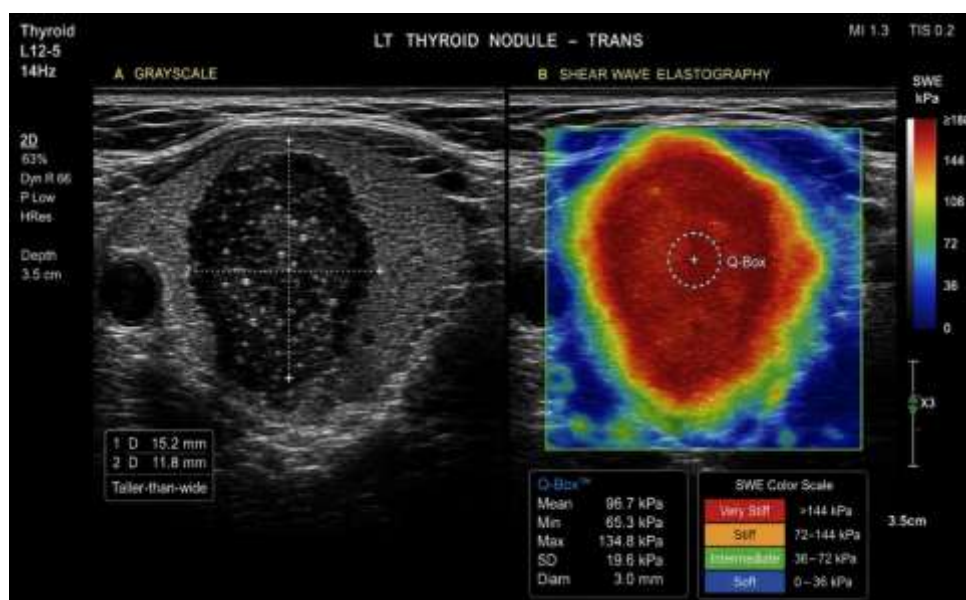


Figure 9. Representative combined ultrasound examination of a malignant thyroid nodule. (A) Grayscale ultrasound showing suspicious malignant features including marked hypoechogenicity, irregular margins, microcalcifications, and taller-than-wide morphology. (B) Corresponding shear wave elastography demonstrating markedly

increased stiffness (mean SWE $\approx$ 96.7 kPa), supporting the diagnosis of papillary thyroid carcinoma.

Discussion

The current study's demographic factors were comparable to those discovered in earlier epidemiologic investigations. Women made up around two thirds of the study sample, much as in the general population with thyroid nodules, which are more common in women. According to Haugen et al., thyroid nodules are more common in women due to hormonal and autoimmune reasons, and only a tiny portion of them turn out to be malignant [14]. Similarly, Alarifi et al. noted that while thyroid nodules are common, the majority of them are benign and emphasized the need of "safe" imaging techniques for sufficient risk assessment [15].

Microcalcifications, uneven edges, hypoechogenicity, taller-than-wide, and enhanced intranodular vascularity were all employed as conventional ultrasonography characteristics in the current investigation and were shown to be substantially linked with malignancy. It closely resembles the TI-RADS classification used by the American College of Radiology. Tessler et al. suggest using these sonographic features in a regular assessment of thyroid ultrasonography because they were the most trustworthy markers of thyroid cancer [16]. However, there are some similarities between benign and malignant sonographic results, especially in the ambiguous nodule, and additional imaging methods like elastography are useful.

One of the main findings of this study was that malignant thyroid nodules had a much greater elasticity measurement. Malignant lesions were consistently shown to be stiffer than benign nodules using both strain elastography and shear wave elastography. The findings align with the systematic review and meta-analysis conducted by Razavi et al., which showed that elastography significantly improves thyroid ultrasound's diagnostic accuracy by providing objective assessments of thyroid tissue stiffness [17]. In a similar vein, Cosgrove et al. emphasized the importance of ultrasound elastography in the assessment of thyroid nodules and its capacity to significantly increase diagnostic confidence when paired with grayscale ultrasonography in the World Federation for Ultrasound in Medicine and Biology (WFUMB) guidelines [18].

Additionally, the present work demonstrates that elasticity parameters derived from quantitative shear wave elastography may corroborate earlier research showing the use of elasticity values in thyroid cancer prediction. According to Aghaghazvini et al., the accuracy of nodule detection was comparable to the current research, and the elasticity values of the malignant nodules were much greater [19]. Our results are consistent and confirm the clinical use and repeatability of quantitative elastographic assessments in different patient populations and ultrasound devices.

The mixture of elastography with conventional ultrasonography produced improved diagnostic performance, which was one of the study's key results. Compared to traditional ultrasound, the imaging combination technique was more sensitive, specific, and diagnostic. According to Trimboli et al.'s comprehensive study [20], multiparametric ultrasonography combined with grayscale imaging and elastography improves the identification of malignant thyroid nodules and reduces the number of needless small needle aspiration biopsies. These two complimentary methods enable simultaneous evaluation of mechanical and morphological characteristics and increase diagnostic confidence.

The study's diagnostic index results were positive, indicating that elastography may be useful in clinical decision-making. Elastography may help identify and treat thyroid cancers earlier by further classifying people with benign thyroid nodules and avoiding

needless invasive treatments. However, as histology is the gold standard for diagnosis, elastographic data should always be utilized in conjunction with conventional ultrasound parameters, the clinical condition, and the cytopathological investigation.

There are certain restrictions on this. The fact that this research only included 90 patients and was conducted at a single tertiary referral institution may have limited the validity of its conclusions. Furthermore, even in cases when testing protocols are standardized, operator experience and technological considerations may have an impact on elastographic values. To confirm the diagnostic accuracy of ultrasonic elastography and expand its usage in regular thyroid imaging, further multicenter studies with greater patient numbers and consistent shear wave elasticity cut-off values are recommended.

4. Conclusion

Ultrasound elastography is a non-invasive imaging method that may be used to distinguish between benign and malignant thyroid nodules. With greater strain ratios, elasticity scores, and shear wave elasticity assessments, the malignant nodules exhibited noticeably more tissue stiffness than the benign lesions. Elastography may be helpful in thyroid nodule risk stratification since it has been shown to have superior diagnostic sensitivity, specificity, and overall accuracy when compared to traditional ultrasonography alone. Thyroid ultrasound elastography may be helpful in reducing needless FNA biopsies (either by raising the specificity of invasive investigation or surgical therapy, or by increasing the sensitivity to choose the patient for future steps of invasive enquiry or surgical treatment). Although histopathology is still the gold standard, elastography may be very helpful in giving additional information to support clinical decision making. In the future, bigger patient cohorts in more multicenter studies are required to reach further consensus quantitative cut-off values and validation in everyday clinical practice of thyroid imaging.

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