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The Diagnostic Accuracy of Strain Elastography in Differentiating Benign and Malignant Thyroid Lesions Keeping Histopathology as Gold Standard

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ABSTRACT

Background: Elastography represents a contemporary technique employed in the assessment of thyroid nodules through the comparison of tissue elasticity. Strain and shear wave elastography are two varieties of elastography currently utilized in clinical settings. The objective of this investigation was to ascertain the diagnostic precision of strain ultrasound elastography in distinguishing between benign and malignant thyroid nodules, utilizing histopathology as the definitive standard. **Objective:** To determine the diagnostic accuracy of strain ultrasound elastography in differentiation between benign and malignant thyroid lesions keeping histopathology as gold standard. **Methodology:** The study at Radiology Department, Mayo Hospital, Lahore from 28 February 2024 to 27 August 2024, included 170 patients with thyroid nodules. Strain ultrasound elastography distinguished benign and malignant nodules by comparing findings with histopathology. Analysis was done using SPSS 25.0 with 2×2 contingency table for sensitivity, specificity, predictive values, and diagnostic accuracy compared to histopathology. **Results:** In this investigation, a cohort of 170 individuals presenting with thyroid nodules was examined. Among these subjects, 57.6% were identified as male and 42.4% as female, with ages spanning from 18 to 80 years, yielding a mean age of 52.95±10.785. Strain elastography exhibited a sensitivity of 86.7%, specificity of 92.0%, positive predictive value of 96.2%, negative predictive value of 74.1%, and an overall accuracy of 88.2% in differentiating benign from malignant lesions. **Conclusion:** Strain elastography represents a noninvasive technique utilized to differentiate between benign and malignant thyroid nodules, in addition to discerning patients who necessitate surgical intervention.

INTRODUCTION

Thyroid lesions are common radiological findings, being more recognized due to increased awareness. Differentiating between benign and malignant thyroid lesions with various clinical and radiological findings remains a challenge. Ultrasound elastography, a non-invasive imaging modality invented in the late 19th century, offers significant clinical benefits.[1-2]

Elastography, a form of ultrasonography like manual palpation, assesses tissue stiffness affected by pathology. Two methods are used: strain elastography, examining tissue deformation from external pressure, and shear wave elastography, studying tissue deformation caused by acoustic shear waves. Ultrasound elastography, known as "Electronic palpation imaging," is a new, non-invasive imaging technique advancing ultrasonography.[1-2]

Elastography, a technique pioneered by Ophir J et al. at the University of Texas Medical School, evaluates the rigidity of tissues by measuring their deformation in response to an external force. This modality identifies relative tissue stiffness or displacement when subjected to applied pressure; tissues with greater rigidity exhibit lesser deformation compared to more compliant tissues. Elastography bears resemblance to manual palpation and demonstrates that malignant lesions possess greater stiffness than their benign lesions.[1,3]

In the investigation, the occurrence of malignant thyroid nodules was observed in 40.65% of the instances. Strain ultrasound elastography exhibited a sensitivity of 88.0% and a specificity of 93.0%, proficiently differentiating between benign and malignant nodules.[4] A contemporary investigation revealed that strain elastography exhibited an impressive sensitivity rate of 100.0% and a specificity rate of 80.2% in differentiating between benign and malignant thyroid nodules.[5]

The literature on strain ultrasound elastography's diagnostic accuracy for distinguishing between benign and malignant thyroid lesions varies. Local statistics are lacking, so our study aims to establish this accuracy. Biopsy, the current gold standard, is invasive and risky, highlighting the need for a reliable, non-invasive assessment method for thyroid nodules. Our study's results will offer our population a cost-effective, easily accessible way to differentiate these lesions, aiding in timely treatment decisions and reducing morbidity and mortality associated with invasive biopsies.

METHODOLOGY

Approval was obtained from the hospital's ethical committee, and written consent was secured from all 170 participants with palpable thyroid nodules at Mayo Hospital, Lahore. The sample size was determined with 95% confidence level. The study included patients from 28 February 2024 to 27 August 2024, meeting the eligibility criteria. The prevalence of malignant thyroid nodules was 40.65%. Strain ultrasound elastography had a sensitivity of 88.0% and specificity of 93.0% in distinguishing benign from malignant nodules.[4]

Patients aged 18-80 with persistent thyroid nodules underwent strain ultrasound elastography to categorize nodules as benign or malignant. Exclusions: history of thyroid surgery or confirmed diagnosis. Procedure conducted using a high-resolution ultrasound machine by a consultant radiologist with 3+ years of experience, in the researcher's presence.

Following ultrasound assessment, patients underwent histopathological confirmation via fine-needle aspiration biopsy in the ward. Tissue samples were sent to the pathology lab for analysis. Histopathology reports were compared with strain ultrasound elastography findings. Data on patient demographics, elastography results, and histopathology were recorded on a proforma for analysis in SPSS 25. Mean, standard deviation, frequency, and percentages were calculated. 2×2 contingency tables determined sensitivity, specificity, and other values for strain ultrasound elastography in distinguishing benign from malignant thyroid lesions with histopathology as the standard. Stratification controlled for age, gender, disease duration, and lesion size, with post-stratification accuracy calculated.

RESULTS

In this study, 170 patients with thyroid nodules were analyzed. Of these, 57.6% were males and 42.4% were females, with an age range of 18 to 80 years (mean age: 52.95±10.785 years). The majority (34.1%) were ≤50 years old, while 65.9% were >50 years old. The average nodule size was 2.5±1.3 cm, with 68.2% of patients having nodules ≤2 cm. The average nodule duration was 5.65±1.6 months, with 53.5% having nodules for ≤3 months. Histopathology showed 70.6% of nodules as malignant and 29.4% as benign. Strain elastography identified 63.5% as malignant and 36.5% as benign (Table-1).

Sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV) and accuracy of strain elastography in differentiating benign and malignant lesions was 86.7%, 92.0%, 96.2%, 74.1% and 88.2% respectively (Table-2). Stratification of findings of lesions on histopathology and strain elastography with respect to gender, age, size and duration of nodule has been done and showed high sensitivity and specificity in each stratum (Table-3 to 6).

Table 1

Frequency distribution of different variables

Variables		Frequency	Percent
Gender	Male	98	57.6%
	Female	72	42.4%
	Total	170	100.0%
Age groups	≤50 years	58	34.1%
	>50 years	112	65.9%
	Total	170	100.0%
Nodule Size	≤2 cm	116	68.2%
	>2 cm	54	31.8%
	Total	170	100.0%
Duration	≤5 months	91	53.5%
	>5 months	79	46.5%
	Total	170	100.0%
Histopathology	Malignant	120	70.6%
	Benign	50	29.4%
	Total	170	100.0%
Strain Elastography	Malignant	108	63.5%
	Benign	62	36.5%
	Total	170	100.0%

Figure 1

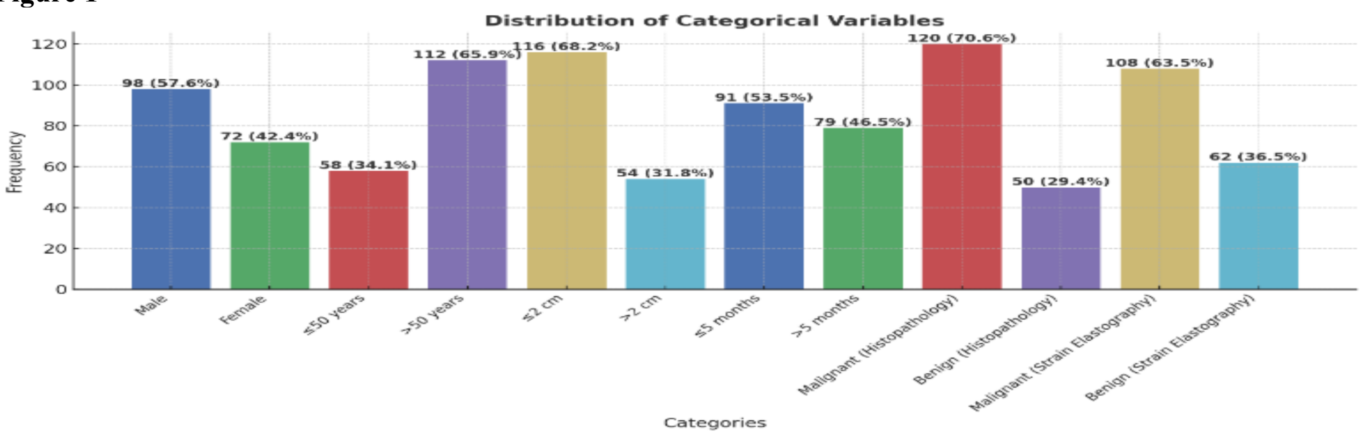


Table 2

Findings of lesions on histopathology and strain elastography

Lesions on strain elastography	Lesions on Histopathology		Total	
	Malignant	Benign		
Malignant	104	4	108	Sn=86.7% Sp=92.0% PPV=96.2% NPV=74.1% Accuracy=88.2%
Benign	16	46	62	
Total	120	50	170	

Table 3

Stratification of findings of lesions on histopathology and strain elastography with respect to gender

Gender	Lesions on strain elastography	Lesions on Histopathology		Total	
		Malignant	Benign		
Male	Malignant	60	1	61	Sn=89.5%
	Benign	7	30	37	Sp=96.7% PPV=98.3%
	Total	67	31	98	NPV=81.1% DA=91.8%
Female	Malignant	44	3	47	Sn=83.1%
	Benign	9	16	25	Sp=84.2% PPV=93.6%
	Total	53	19	72	NPV=64.0% DA=83.3%

Table 4

Stratification of findings of lesions on histopathology and strain elastography with respect to age groups

Age group	Lesions on strain elastography	Lesions on Histopathology		Total	
		Malignant	Benign		
≤50 years	Malignant	40	0	40	Sn=83.3% Sp=100.0%
	Benign	8	10	18	PPV=100.0%
	Total	48	10	58	NPV=55.5% DA86.2%
>50 years	Malignant	64	4	68	Sn=88.8% Sp=90.0%
	Benign	8	36	44	PPV=94.1%
	Total	72	40	112	NPV=81.8% DA=89.2%

Table 5

Stratification of findings of lesions on histopathology and strain elastography with respect to size of nodule

Size of nodule	Lesions on strain elastography	Lesions on Histopathology		Total	
		Malignant	Benign		
≤2 cm	Malignant	65	4	69	Sn=85.5% Sp=90.0%
	Benign	11	36	47	PPV=94.2% NPV=76.5%
	Total	76	40	116	DA=87.1%
>2 cm	Malignant	39	0	39	Sn=88.6%,
	Benign	5	10	15	Sp=100.0%, PPV=100.0%,
	Total	44	10	54	NPV=66.7%, DA=90.7%

Figure: 2

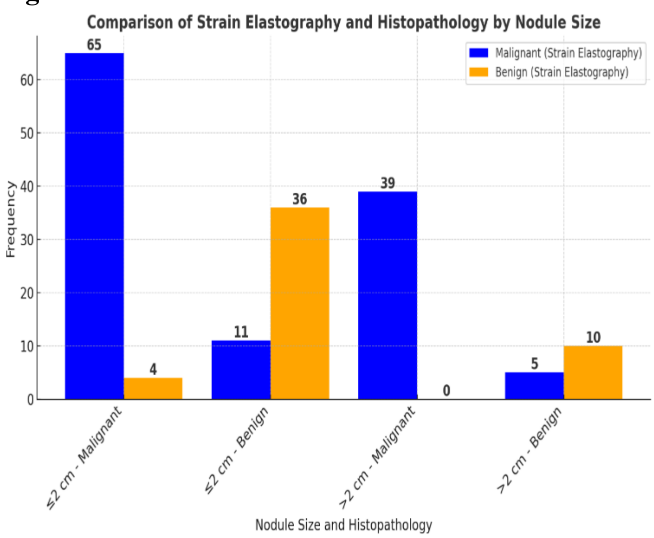
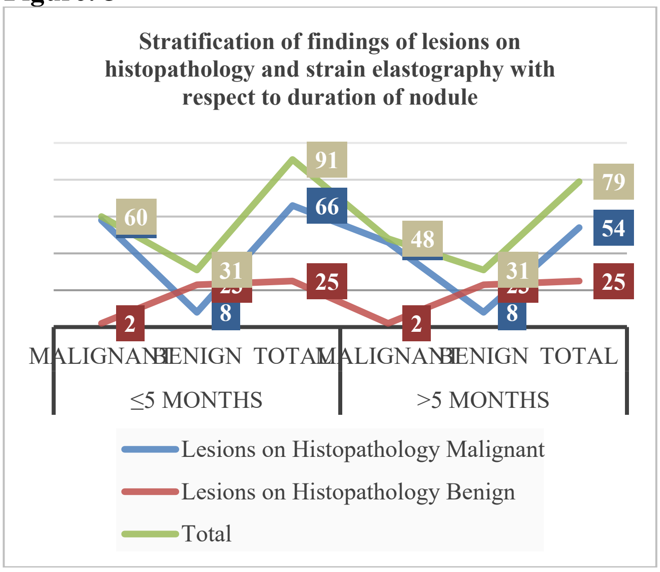


Table 6

Stratification of findings of lesions on histopathology and strain elastography with respect to duration of nodule

Duration of nodule	Lesions on strain elastography	Lesions on Histopathology		Total	
		Malignant	Benign		
≤5 months	Malignant	58	2	60	Sn=87.8% Sp=92.0%
	Benign	8	23	31	PPV=96.7% NPV=74.1%
	Total	66	25	91	DA=89.1%
>5 months	Malignant	46	2	48	Sn=85.1% Sp=92.0%
	Benign	8	23	31	PPV=95.8% NPV=74.1%
	Total	54	25	79	DA=87.3%

Figure: 3



DISCUSSION

Thyroid nodules are common, mostly noncancerous, and their prevalence varies with population and detection methods. Female sex, age, iodine deficiency, and radiation exposure are risk factors. Palpation, ultrasonography, and FNAB play roles in diagnosis. High-resolution ultrasonography and elastography aid in determining the need for surgery, especially with inconclusive cytology.[6-7]

Elastography, a recent method for assessing thyroid nodules, compares tissue elasticity. Clinical practice still employs strain and shear-wave elastography (SWE). Strain elastography assesses two types of elasticity. It visually scores nodule colors based on a 4-5 scale system and specifies target and reference regions for evaluation.[8-9]

The elastograph automatically calculates the strain ratio, indicating a higher probability of malignancy with increased strain ratio. SWE generates a quantitative elastic value by stimulating tissues with an ultrasound probe's acoustic pulse, offering real-time elastograms. Clinical assessment of thyroid nodules utilizes methods like supersonic shear wave and acoustic radiation force impulse.[9]

Our investigation revealed that strain ultrasound elastography exhibited an overall sensitivity of 86.7%, specificity of 92.0%, positive predictive value of 96.2%, negative predictive value of 74.1%, and diagnostic accuracy of 88.2% in differentiating between benign and malignant thyroid nodules in comparison to histopathological findings. In another research endeavor, a prevalence rate of 40.65% for malignant thyroid nodules was documented, with strain ultrasound elastography displaying a sensitivity of 88.0% and specificity of 93.0% in the distinction of benign from malignant nodules.[10]

A recent investigation revealed that strain elastography exhibited substantial precision in distinguishing benign from malignant thyroid nodules. A meta-analysis encompassing 639 nodules demonstrated encouraging outcomes, with an average sensitivity of 92% and specificity of 90%. Nevertheless, a later extensive study conducted by Moon et al involving 703 nodules contested these preliminary conclusions.[11-13]

The performance of strain elastography (SE) was evaluated utilizing the Asteria and Rago criteria, revealing diminished sensitivity (65.4%) and negative predictive value (NPV) (79.1%) in contrast to gray-scale ultrasound, which demonstrated a sensitivity of 91.7% and an NPV of 94.7%. The authors concluded that SE was not advantageous for the recommendation of fine needle aspiration biopsy (FNAB). Additionally, another investigation involving 237 thyroid nodules (58 of which were malignant) indicated inferior performance of real-time elastography (RTE) when compared to gray-scale ultrasound.[14]

In a longitudinal investigation conducted by Azizi et al., the application of a four-tiered elasticity scoring system to assess 912 nodules revealed a positive predictive value (PPV) of 36.1%, surpassing that of microcalcifications (35.9%) and demonstrating a statistically significant advantage over hypo-echogenicity (13.6%) and isthmus positioning (16.9%). The elasticity score exhibited a negative predictive value (NPV) of 97.2%, identifying it as the most reliable indicator for malignancy. This study, which encompasses the largest sample of nodules within the domain of serological evaluation, effectively mitigated the patient selection bias prevalent in prior investigations.[15]

In their investigation involving 132 nodules, Ragazzoni et al. determined that elastography classified 77 of the 92 benign nodules as score 1 or 2, while 34 of the 40 malignant nodules were designated as score 3 or 4. This resulted in a sensitivity of 85%, a specificity of 83.7%, a positive predictive value of 69.3%, and a negative predictive value of 92.7%.[16] Asteria et al. conducted an evaluation of 17 malignant and 69 benign lesions, demonstrating elastography's sensitivity of 94.1%, specificity of 81%, positive predictive value (PPV) of 55.2%, negative predictive value (NPV) of 98.2%, and an accuracy rate of 83.7%.[17]

In their study, Ferrari et al found that most benign nodules (78%) fell into patterns 1-2, while the majority of malignant nodules (88%) were in patterns 3-4. Additionally, elastography showed sensitivity of 88%, specificity of 78%, PPV of 72%, NPV of 91%, and diagnostic accuracy of 82%.[18]

Cantisani et al studied 97 patients, reporting elastography's sensitivity at 97.3% and specificity at 91.7%. Lesions with strain ratio ≥2 were predominantly malignant.[19] In research conducted by Cantisani et al., the investigation encompassed 89 benign and 58 malignant cases following thyroidectomy. The findings revealed sensitivity and specificity rates of 93% and 89%, respectively, utilizing an elastography score threshold of 2. This research determined that elastography exhibited greater accuracy in comparison to traditional ultrasound and color Doppler ultrasound techniques.[20]

Shweel and Mansour elucidated that elastography exhibited a sensitivity of 75.4%, specificity of 85.5%, positive predictive value (PPV) of 71.4%, negative predictive value (NPV) of 90.5%, and an accuracy rate of 86.7%. Furthermore, they observed that the diagnostic efficacy of elastography was enhanced when utilized in conjunction with high-resolution ultrasound.[21]

In a comprehensive meta-analysis encompassing 24 studies with a total of 2624 participants and 3531 thyroid nodules, the utilization of strain elastography (SE) demonstrated superior diagnostic efficacy compared to ultrasound (US) characteristics. The calculated sensitivities and specificities for the various assessed features were as follows: elasticity score (82%, 82%); strain ratio (89%, 82%); hypoechogenicity (78%, 55%); microcalcifications (50%, 80%); irregular margins

(66%, 81%); absence of halo sign (56%, 57%); vertical growth of nodules (46%, 77%); and intranodular vascularization (40%, 61%). Furthermore, the integration of ultrasound elastography (USE) was observed to significantly improve the diagnostic accuracy of ultrasound.[22]

In a comprehensive meta-analysis conducted by Ghajarzadeh et al., a total of 12 studies encompassing 1180 thyroid nodules were scrutinized to evaluate the efficacy of sonoelastography in identifying malignant nodules. The investigation revealed that an elasticity score threshold ranging from 1 to 2 resulted in a sensitivity of 98.3%. Furthermore, the findings suggest that patients presenting an elasticity score of 1 may not necessitate any additional invasive diagnostic procedures.[23]

In their investigation, Akcay et al examined 110 nodules utilizing ultrasound elastography assessed by stiffness scoring. They determined a sensitivity of 100%, specificity of 95%, positive predictive value (PPV) of 40%, and a negative predictive value (NPV) of 100%, applying a malignancy cut-off score of 4. They recommended performing biopsies for all nodules rated 4, while advising against biopsy for those rated 1.[24]

In a study with 50 patients having 73 thyroid nodules (16 malignant and 57 benign), US elastography scored benign nodules 1-3 and carcinoma nodules 4-5 with 93.3% sensitivity, 100% specificity, and 97.8% accuracy. Combining US and elastography, hypoechogenicity/score 4-5 was the most predictive feature for malignancy (80% sensitivity, 100% specificity, 93.4% accuracy). Strain ratio (SR) cutoff for malignancy was 2.3, with 5 nodules having SR between 2.31-4 (96% sensitivity, 83% specificity).[25]

Asari et al found that real-time USE determines tissue deformability under compression, enabling objective measurement of maximum diameter inconclusive on conventional ultrasound. An elasticity score of 4-5 strongly indicated malignancy, showing 90.63% sensitivity, 89.47% specificity, and 90.20% accuracy.[26]

Asteria et al found that ultrasound elastography (USE) showed a sensitivity of 94.1%, specificity of 81%, positive predictive value (PPV) of 55.2%, negative predictive value (NPV) of 98.2%, and an accuracy of 83.7% in diagnosing thyroid cancer.[27]

CONCLUSION

Strain elastography, a technique measuring tissue stiffness, distinguishes between benign and malignant thyroid nodules and helps identify surgical candidates, offering a noninvasive method to assess nodules, aid in clinical decisions, and potentially reduce unnecessary surgeries.

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