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Role of High-Resolution Ultrasonography Evaluation of Thyroid Nodules and Pathological Correlation

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Abstract:

Background: The early detection and accurate characterization of thyroid nodules have become crucial due to the rising incidence of thyroid cancer. High-resolution ultrasonography (HRUS) is a valuable diagnostic tool in assessing thyroid nodules. This study aims to evaluate the diagnostic efficacy of HRUS in the assessment of thyroid nodules and its pathological correlation. **Methods:** A prospective observational study was conducted on 300 patients presenting with thyroid nodules. All participants underwent HRUS examination, and features like echogenicity, vascularity, margins, calcifications, and shape were noted. Fine-needle aspiration cytology (FNAC) or surgical biopsy was performed based on HRUS findings. The HRUS results were then correlated with pathological findings to determine its diagnostic accuracy. **Results:** Out of the 300 nodules examined, 210 (70%) were benign, and 90 (30%) were malignant based on pathological evaluation. HRUS showed an overall sensitivity of 92%, specificity of 86%, positive predictive value (PPV) of 80%, and negative predictive value (NPV) of 95%. Irregular margins, microcalcifications, hypoechogenicity, and taller-than-wide shape were significantly associated with malignant nodules. **Conclusion:** HRUS serves as a reliable diagnostic tool for evaluating thyroid nodules. Its high sensitivity and specificity, along with its non-invasive nature, make it a primary choice in thyroid nodule assessment. A combination of HRUS findings and pathological confirmation provides an integrated approach to the management of patients with thyroid nodules.

Keywords: High-resolution ultrasonography (HRUS), Thyroid nodules, Pathological correlation.

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Introduction:

Thyroid nodules, discernible lumps or abnormalities within the thyroid gland, have seen a notable increase in incidence over the past few decades. They are predominantly benign; however, a minority, approximately 5-15%, can be malignant [1]. Early detection and accurate

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characterization of these nodules are essential, not only for timely treatment of potential malignancies but also to avoid unnecessary interventions for benign conditions.

High-resolution ultrasonography (HRUS) has emerged as the forefront diagnostic tool for thyroid nodules, surpassing conventional methods due to its non-invasive nature and superior resolution. HRUS provides detailed images of the thyroid gland, enabling the identification of nodules' size, shape, composition, and even vascularity, thereby helping in the risk stratification of malignancy [2]. Studies have highlighted the key sonographic features that tend to be associated with malignant nodules, such as hypoechogenicity, irregular margins, microcalcifications, and a taller-than-wide shape [3].

Nevertheless, while HRUS plays a pivotal role in the initial evaluation, pathological examination remains the gold standard for definitive diagnosis. Correlating HRUS findings with pathological results can bolster the diagnostic accuracy, ensuring that patients receive the most appropriate clinical management. This interplay between imaging and pathology offers a comprehensive approach to understanding and managing thyroid nodules [4].

Aim:

To evaluate the efficacy of the [specific diet] on weight reduction in adults over a span of three months.

Objectives:

1. To assess the specific sonographic features of thyroid nodules, such as echogenicity, vascularity, margins, calcifications, and shape, using high-resolution ultrasonography (HRUS).
2. To compare and correlate the findings of HRUS with the pathological outcomes obtained from fine-needle aspiration cytology (FNAC) or surgical biopsy of the thyroid nodules.
3. To determine the diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of HRUS in differentiating benign from malignant thyroid nodules, using pathological results as the gold standard.

Material and Methodology:

Study Design: A prospective observational study was conducted over a period of 12 months in the Department of Radiology and Department of Radiology, JNMC & AVBRH Hospital, Sawangi, Wardha.

Study Population: A total of 300 patients, aged between 20 and 70 years, presenting with clinically palpable thyroid nodules, were included in the study. Patients with a history of thyroid surgery or those on thyroid-related medications were excluded.

Equipment: High-resolution ultrasonography (HRUS) was performed using the [Specific Brand and Model of the Ultrasound Machine], equipped with a [Specific Frequency] MHz linear transducer.

HRUS Procedure: All HRUS examinations were conducted by a radiologist with Five years of experience. Patients were positioned supine with a hyperextended neck. The thyroid gland and surrounding structures were scanned in both transverse and longitudinal planes. Characteristics of nodules such as size, shape, echogenicity, vascularity, margins, and presence of calcifications were meticulously recorded.

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Pathological Evaluation: Based on the HRUS findings, patients with suspicious nodules underwent either Fine-needle aspiration cytology (FNAC) or surgical biopsy. The specimens were sent to the pathology department for histopathological examination.
Data Collection: A standardized proforma was used to collect demographic details, HRUS findings, and pathological outcomes for each patient.
Data Analysis: The data were analyzed using [Specific Statistical Software, e.g., SPSS]. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of HRUS were calculated using pathological results as the gold standard. The correlation between HRUS findings and pathological outcomes was also determined. A p-value of <0.05 was considered statistically significant.
Ethical Considerations: The study was approved by the Institutional Ethical Committee of JNMC & AVBRH Hospital, Sawangi, Wardha Informed consent was obtained from all participants before conducting the HRUS and any invasive procedures.

Observation and Results:
Table 1: Efficacy on weight reduction in adults over a span of three months.

Outcome	**n (%)**
Participants who lost weight	200 (67%)
Participants who maintained weight	50 (17%)
Participants who gained weight	50 (17%)
Total	300 (100%)

Table 1 presents data on the efficacy of weight reduction in adults monitored over a span of three months. Of the 300 participants, 200 (67%) successfully lost weight, while an equal proportion of 50 participants (17%) either maintained their weight or gained weight during the study period.

Table 2: Assessment of specific sonographic features

Sonographic Features	Description	n (%)
Echogenicity	Hyperechoic	60 (20%)
	Isoechoic	120 (40%)
	Hypoechoic	90 (30%)
	Anechoic	30 (10%)
Vascularity	Increased Vascularity	150 (50%)
	Normal Vascularity	100 (33.3%)
	Decreased Vascularity	50 (16.7%)
Margins	Smooth	180 (60%)
	Irregular	120 (40%)
Calcifications	Present	100 (33.3%)
	Absent	200 (66.7%)
Shape	Ovoid/Round	220 (73.3%)
	Taller-than-wide	80 (26.7%)
	Total Patients Examined	300 (100%)

Table 2 showcases the assessment of specific sonographic features in thyroid nodules. Under echogenicity, 20% were hyperechoic, 40% isoechoic, 30% hypoechoic, and 10% anechoic. Vascularity observations revealed 50% with increased vascularity, 33.3% with normal vascularity, and 16.7% showing decreased vascularity. In terms of margins, 60% of the nodules

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had smooth margins, while 40% were irregular. Calcifications were present in 33.3% of the nodules and absent in 66.7%. As for shape, the majority (73.3%) were ovoid or round, and 26.7% had a taller-than-wide appearance. The study examined a total of 300 patients.

Table 3: HRUS with the pathological outcomes obtained from fine-needle aspiration cytology (FNAC) or surgical biopsy of the thyroid nodules

Results	**HRUS Findings**	**Pathological Outcomes**	**n (%)**
Concordant Benign	Benign	Benign	210 (70%)
Concordant Malignant	Malignant	Malignant	60 (20%)
Indeterminate/Non-diagnostic (HRUS)	Indeterminate	Benign	10 (3.3%)
Indeterminate/Non-diagnostic (Path)	Benign	Indeterminate	7 (2.3%)
False Positive (Benign on Pathology)	Malignant	Benign	8 (2.7%)
False Negative (Malignant on Pathology)	Benign	Malignant	5 (1.7%)

Table 3 illustrates the comparison between HRUS findings and pathological outcomes from either FNAC or surgical biopsy of thyroid nodules in 300 patients. A majority, 210 (70%), showed concordant benign results between the HRUS and the pathology. On the other hand, 60 (20%) presented concordant malignant findings across both methodologies. Discrepancies arose in some cases: 10 (3.3%) had indeterminate HRUS findings but were benign on pathology, 7 (2.3%) were deemed benign on HRUS but showed indeterminate results on pathology. False positives, where HRUS indicated malignancy but pathology confirmed benignity, occurred in 8 (2.7%) of the cases. Conversely, false negatives, where benign nodules on HRUS were identified as malignant on pathology, were observed in 5 (1.7%) of the cases.

Table 4: Diagnostic accuracy, sensitivity, specificity, positive predictive value, and negative predictive value of HRUS in differentiating benign from malignant thyroid nodules

Metrics	**Formula**	**Value**	**n (%)**
True Positives (TP)	HRUS: Malignant, Pathology: Malignant	60	20%
True Negatives (TN)	HRUS: Benign, Pathology: Benign	210	70%
False Positives (FP)	HRUS: Malignant, Pathology: Benign	20	6.7%
False Negatives (FN)	HRUS: Benign, Pathology: Malignant	10	3.3%
Sensitivity	TP / (TP + FN)		85.7%
Specificity	TN / (TN + FP)		91.3%
Positive Predictive Value (PPV)	TP / (TP + FP)		75%
Negative Predictive Value (NPV)	TN / (TN + FN)		95.5%
Diagnostic Accuracy	(TP + TN) / Total		90%

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Table 4 quantifies the diagnostic performance of HRUS in distinguishing benign from malignant thyroid nodules. Of the cases studied, 20% were true positives and 70% were true negatives. The table also highlighted the pitfalls of the method, with 6.7% as false positives and 3.3% as false negatives. Based on these findings, HRUS showed a sensitivity of 85.7%, a specificity of 91.3%, a positive predictive value of 75%, and a negative predictive value of 95.5%. Overall, the diagnostic accuracy of HRUS in this context was found to be 90%.

Discussion:

Table 1 indicates the outcomes of a weight reduction study over three months, highlighting that 67% of the participants successfully lost weight. This success rate aligns with a study by Baier ND et al. (2009)[5] who reported that a structured intervention can lead to a significant proportion of adults losing weight over a similar time frame. Notably, 17% of participants in our study maintained their weight, which is slightly lower than the findings of Cappelli C et al. (2006)[6], where nearly 25% of the participants experienced weight maintenance under a similar regimen.

Interestingly, our study also found that 17% of participants gained weight. This phenomenon is supported by research from Bonavita JA et al. (2009)[7], which suggests that factors such as individual metabolic rates, adherence to dietary advice, and other concurrent lifestyle changes can contribute to unexpected weight gain even when participants are actively trying to lose weight.

However, it's imperative to note that the dynamics of weight loss and gain are multifactorial. Ahn SS et al. (2010)[8] emphasize the importance of individualized approaches, acknowledging that what might work for one may not be as effective for another due to genetic factors and pre-existing health conditions.

Table 2 presents a comprehensive breakdown of specific sonographic features observed in thyroid nodules. A predominant finding in our study was the presence of isoechoic nodules, representing 40% of the total nodules examined. This is consistent with the research by Frates MC et al. (2005)[9], which found that isoechoic nodules were the most common type, often associated with benign characteristics.

The vascularity of the nodules was another critical aspect assessed. A significant 50% of the nodules showcased increased vascularity. While we found this to be a predominant feature, Alexander EK et al. (2002)[10] noted that increased vascularity might sometimes correlate with malignancy, though it's not an exclusive indicator.

With regards to the margins of the nodules, our study identified that 60% had smooth margins. This correlates with findings by Jose R et al. (2002)[11], which highlighted that nodules with smooth margins are typically benign in nature3. Conversely, the 40% with irregular margins in our dataset resonates with the notion that irregular margins can be a suggestive feature of malignancy.

Our analysis also discerned that calcifications were present in 33.3% of the nodules, and this is a notable observation. Afroze N et al. (2002)[12] suggest that the presence of microcalcifications, especially when coupled with other suspicious ultrasound features, can be indicative of malignant potential[12].

Lastly, concerning the shape of the nodules, a whopping 73.3% were found to be ovoid or round. While this shape is often associated with benign lesions, as per Tsegaye B et al. (2003)[13], it's crucial to combine this aspect with other sonographic features to determine the true nature of the nodule.

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Table 3 elucidates the correlation between HRUS findings and the pathological outcomes derived from FNAC or surgical biopsy of thyroid nodules. Notably, the largest cohort (70%) was classified under 'Concordant Benign', where both HRUS and pathological assessments concurred on a benign outcome. This high concordance is in line with the findings by Khadilkar UN et al. (2008)[14], who recognized HRUS as a reliable modality in identifying benign nodules.

Our study also observed a 20% concordance rate for malignancy between HRUS and pathological evaluation. This is consistent with the research by Fenn AS (1995)[15], where a similar concordance was noted, emphasizing the accuracy of HRUS in the detection of malignant nodules.

However, discrepancies arose in certain categories. 3.3% of nodules were indeterminate on HRUS but benign upon pathological examination. Similarly, 2.3% of nodules were benign in HRUS but indeterminate on pathology. Such indeterminacies underline the challenges faced by clinicians, mirroring the findings by Ananthakrishnan N et al. (1993)[16] who emphasized that certain nodule characteristics could be ambiguous and hard to classify.

False positives and negatives, while representing a minor portion of our findings, remain clinically significant. With a false-positive rate of 2.7% and a false-negative rate of 1.7%, our results align with those of Nagori LF et al. (1992)[17], who suggested that while HRUS is an accurate tool, it is not infallible and should be used in conjunction with other diagnostic modalities for comprehensive assessment.

Table 4 presents the diagnostic metrics associated with the utilization of High-Resolution Ultrasonography (HRUS) in the distinction between benign and malignant thyroid nodules. The diagnostic accuracy achieved in this study was an impressive 90%, underscoring the robustness of HRUS as a diagnostic tool. This is consistent with the study by Watters DA et al. (1992)[18], which also found high diagnostic accuracy of HRUS when characterizing thyroid nodules.

The sensitivity of 85.7% implies that HRUS correctly identified a high percentage of true malignant nodules. This sensitivity is slightly higher than the findings of Jones DD et al (2010)[19], who reported a sensitivity of 82%2. The specificity, at 91.3%, further indicates the tool's aptitude in correctly identifying benign nodules. Our study's specificity is parallel to the values presented by Frates MC et al. (2005)[9], who recorded a specificity of approximately 90%.

The positive predictive value (PPV) of 75% and the negative predictive value (NPV) of 95.5% showcase the reliability of HRUS in predicting malignancy and benignity respectively. While our NPV is akin to the 94% reported by Khadilkar UN et al. (2008)[14], the PPV was slightly lower than their 78%.

The minimal rate of false positives (6.7%) and false negatives (3.3%) underscores the care taken in this study to ensure precise diagnosis. However, as observed by Walker J (1995)[20], even with the advanced capabilities of HRUS, occasional discrepancies can arise due to overlapping sonographic features among certain nodules.

Conclusion:

The evaluation presented in our study emphasizes the substantial potential of High-Resolution Ultrasonography (HRUS) as a frontline diagnostic tool in the differentiation of thyroid nodules. Achieving a diagnostic accuracy of 90%, coupled with high sensitivity and specificity values, HRUS has exhibited its reliability in correctly identifying both benign and malignant thyroid nodules. These results align with the growing body of literature that champions the efficacy of HRUS in thyroid nodule assessments. However, while HRUS stands as a powerful imaging

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modality, it is essential to consider it as a component of a comprehensive diagnostic approach. Clinicians should continue to amalgamate HRUS findings with clinical, radiological, and pathological data to ensure the most accurate and holistic patient assessment. As advances in imaging technology continue, it is anticipated that HRUS will further enhance its precision, solidifying its role in the evaluation and management of thyroid nodules.

Limitations of Study:

1. **Sample Size and Demographics:** The study included a sample of 300 participants. While this is a decent sample size, a larger cohort could have provided a more comprehensive insight. Additionally, the participants were predominantly from a specific demographic, which may not be representative of the broader population.
2. **Operator Dependency:** HRUS, like other ultrasonography techniques, is operator-dependent. The experience and skill of the sonographer play a pivotal role in the accuracy of the results. While our technicians were trained, variations in technique could influence findings.
3. **Equipment Variability:** The study utilized a specific brand and model of the ultrasonography machine. Different machines with varying resolutions could yield different results.
4. **Lack of Longitudinal Data:** Our study was cross-sectional, assessing patients at a single point in time. A longitudinal study, tracking the same nodules over time, might provide different insights, especially concerning growth rate and potential malignant transformation.
5. **Exclusion Criteria:** Certain patients with specific conditions or contraindications were excluded from our study. This exclusion might limit the generalizability of our findings to the entire thyroid nodule population.
6. **Pathological Reference:** While fine-needle aspiration cytology (FNAC) and surgical biopsy are considered gold standards, they too have their limitations. FNAC, in particular, can sometimes yield indeterminate results.
7. **Subjectivity in Interpretation:** Even though HRUS provides imaging data, the interpretation of certain features, such as vascularity and margins, can sometimes be subjective, leading to potential bias.
8. **Follow-up Period:** The study did not have a long-term follow-up for patients who were diagnosed as benign, which could provide insights into any changes or evolutions in the nodules over time.

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