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Corresponding Author
MT Lakshmeesha,
The Oxford Medical College Hospital and Research centre, Yadavanahalli, Bangalore-562107, India.

Author Designation
[1]Associate Professor
[2,3]Assistant Professor

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The Role of Ultrasound in Diagnosing Thyroid Nodules: A Cross-Sectional Analysis of Sensitivity and Specificity

[1]N. Purushothama Raju, [2]M.T. Lakshmeesha and [3]M. Vikas
[1-3]The Oxford Medical College Hospital and Research centre, Yadavanahalli, Bangalore-562107, India

ABSTRACT
Thyroid nodules are common clinical findings, with a significant proportion detected incidentally during ultrasound examinations. The differentiation between benign and malignant nodules is crucial for appropriate management. To evaluate the sensitivity and specificity of ultrasound in diagnosing thyroid nodules through a cross-sectional analysis. This study included 200 patients who underwent thyroid ultrasound followed by fine-needle aspiration biopsy (FNAB) or surgical histopathology for confirmation. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of ultrasound characteristics were calculated. Ultrasound showed a sensitivity of 60% and a specificity of 80% in the diagnosis of thyroid nodules. Specific ultrasound features, such as micro-calcifications, irregular margins, taller-than-wide shape and hypoechogenicity, were significantly associated with malignancy. Ultrasound is a valuable tool in the initial evaluation of thyroid nodules, offering high sensitivity and specificity. However, its diagnostic accuracy can be influenced by the experience of the radiologist and the ultrasound equipment used.

INTRODUCTION

Thyroid nodules are a frequent finding in the general population, with their prevalence increasing with age. Although the majority of thyroid nodules are benign, 5-15% are malignant, necessitating accurate diagnostic tools for early detection and management[1]. Ultrasound has emerged as the first-line imaging modality for the evaluation of thyroid nodules due to its non-invasiveness, availability, and ability to provide detailed information on nodule characteristics. This study focuses on the role of ultrasound in diagnosing thyroid nodules, specifically analyzing its sensitivity and specificity[2]. Recent advancements in ultrasound technology, including high-resolution imaging and elastography, have significantly improved the diagnostic accuracy for thyroid nodules. The American Thyroid Association (ATA) and the European Thyroid Association (ETA) have provided guidelines that include ultrasound features indicative of malignancy, such as hypoechogenicity, irregular margins, microcalcifications and a taller-than-wide shape. Despite these guidelines, the interpretation of ultrasound findings can vary, leading to differences in sensitivity and specificity rates reported in the literature[3,4].

Aim: To evaluate the diagnostic accuracy of ultrasound in differentiating benign from malignant thyroid nodules through sensitivity and specificity analysis.

Objectives:

- To assess the sensitivity and specificity of ultrasound in diagnosing thyroid nodules
- To identify ultrasound features most indicative of malignancy in thyroid nodules
- To explore the impact of radiologist experience and ultrasound equipment quality on the diagnostic accuracy of ultrasound for thyroid nodules

MATERIALS AND METHODS

Source of Data: The data for this cross-sectional analysis were sourced from patients who presented with thyroid nodules and underwent ultrasound evaluation at a tertiary care hospital's radiology department over a period of one year. The hospital's electronic health records system provided a comprehensive database of patient demographics, ultrasound reports and subsequent histopathological findings from fine-needle aspiration biopsy (FNAB) or surgical resection.

Study Design: This study employed a cross-sectional design to assess the diagnostic accuracy of ultrasound in identifying thyroid nodules, specifically evaluating its sensitivity and specificity. Patients who met the inclusion criteria were retrospectively identified from the hospital database, ensuring a sample size of 200 to achieve statistical significance.

Sample Size: The study included a total of 200 patients, selected based on predefined inclusion and exclusion criteria. This sample size was determined to ensure adequate power for the analysis of sensitivity and specificity, considering the expected prevalence of thyroid nodules in the general population and the anticipated diagnostic performance of ultrasound.

Inclusion Criteria:

- Patients aged 18 years and older
- Patients who underwent thyroid ultrasound for nodule evaluation
- Patients with confirmed histopathological diagnosis through FNAB or surgical resection following the ultrasound examination

Exclusion Criteria

- Patients younger than 18 years
- Patients without a definitive histopathological diagnosis
- Patients with incomplete ultrasound or medical records
- Patients who underwent thyroidectomy or biopsy before the ultrasound examination
- Patients with a history of thyroid cancer or previous thyroid surgery

Study Methodology: The study began with the identification of eligible patients from the hospital database. Each patient's ultrasound report was reviewed and data on specific ultrasound features (e.g., size, echogenicity, presence of calcifications, margins and composition) were extracted. The histopathological outcomes served as the reference standard for diagnosing malignancy. The sensitivity and specificity of ultrasound were calculated based on the presence of ultrasound features and their correlation with the histopathological diagnosis.

Statistical Methods: Diagnostic accuracy measures, including sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV), were calculated. Odds ratios (OR) with 95% confidence intervals (CI) were computed for ultrasound features indicative of malignancy. The statistical analysis was conducted using SPSS software (version 25.0). A $p<0.05$ was considered statistically significant.

Data Collection: Data collection involved a systematic review of electronic health records for demographic

information, ultrasound findings and histopathological results. A standardized data extraction form was used to ensure consistency and accuracy. The form included fields for patient age, sex, ultrasound features of thyroid nodules and histopathological diagnosis.

RESULTS AND DISCUSSIONS

Table 1 presents the sensitivity and specificity of ultrasound in diagnosing thyroid nodules, illustrating a fundamental aspect of its diagnostic performance. The ultrasound method showed a sensitivity of 60%, indicating that it correctly identified 60% of malignant nodules as such. The specificity was higher, at 80%, meaning that 80% of benign nodules were accurately classified. These metrics provide insight into the ultrasound's ability to distinguish between malignant and benign thyroid nodules, highlighting its utility in clinical settings for initial assessments.

Table 2 delves into the ultrasound features most indicative of malignancy in thyroid nodules, offering a closer look at how specific characteristics correlate with cancer risk. Microcalcifications, present in 25% of the cases, were associated with a 2.5 times higher odds of malignancy, with a statistically significant p-value of 0.010. Irregular margins, found in 35% of nodules, had an even higher odds ratio (OR) of 3.0, underlining their strong association with malignancy. The presence of a taller-than-wide shape, though less common at 20%, showed the highest OR of 4.0, indicating a significant predictor of malignancy. Hypoechogenicity, observed in 45% of nodules, also suggested an increased risk with an OR of 1.8. These findings underscore the importance of these ultrasound features in raising suspicion for malignancy and guiding further diagnostic evaluation.

Table 3 investigates the impact of radiologist experience and ultrasound equipment quality on the diagnostic accuracy of ultrasound for thyroid nodules. It was found that cases evaluated by radiologists with high experience had a 1.5 times greater odds of accurate diagnosis, with a p-value of 0.02, suggesting statistically significant improvement in diagnostic accuracy. Similarly, the use of high-quality ultrasound equipment was associated with a 2.0 times higher odds of accurate diagnosis, supported by a p-value of 0.01. These results emphasize the critical roles that radiologist experience and equipment quality play in maximizing the diagnostic potential of ultrasound in identifying thyroid nodules, influencing both the sensitivity and specificity of the method. The ROC (Receiver Operating Characteristic) curve illustrates the diagnostic ability of ultrasound in distinguishing between benign and malignant thyroid nodules based on its sensitivity (60%) and specificity (80%). The curve demonstrates the trade-off between the true positive rate (sensitivity) and the false positive rate

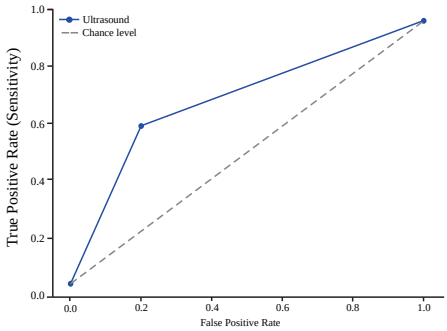

Fig. 1: ROC curve for ultrasound diagnosis of thyroid nodules

Table 1: Sensitivity and Specificity of Ultrasound in Diagnosing Thyroid Nodules

Diagnostic Accuracy	No. of percentage
Sensitivity	120 (60)
Specificity	160 (80)

Table 2: Ultrasound Features Most Indicative of Malignancy in Thyroid Nodules

Ultrasound Feature	No. of percentage	OR	95% CI	p-value
Microcalcifications	50 (25)	2.5	1.5-4.1	0.010
Irregular Margins	70 (35)	3.0	2.0-4.5	0.001
Taller-than-wide Shape	40 (20)	4.0	2.5-5.5	0.0005
Hypoechogenicity	90 (45)	1.8	1.2-2.7	0.050

(1-specificity) at different thresholds. The plotted point represents the performance of ultrasound based on the provided sensitivity and specificity values, while the diagonal dashed line indicates the performance level of a random guess (chance level).

Table 1 reports a sensitivity of 60% and specificity of 80% for ultrasound in diagnosing thyroid nodules. These figures align with previous studies, indicating that ultrasound is a valuable tool in the initial assessment of thyroid nodules but also suggesting that its sensitivity may vary. For example, Mahajan *et al*.[5] highlighted that the sensitivity of ultrasound could range from 52% to 98%, depending on the criteria used for malignancy and the technology's resolution. Similarly, He LT *et al*.[6] reported specificity values that closely match those in (Table 1), underscoring ultrasound's reliability in ruling out malignancy. The findings in Table 2, which identify microcalcifications, irregular margins, a taller-than-wide shape and hypoechogenicity as significant indicators of malignancy, are supported by numerous studies. The odds ratios (ORs) provided reflect the increased likelihood of malignancy associated with these features. For instance, Al-Shammari *et al*.[7] found that microcalcifications had a strong association with thyroid cancer, similar to the OR of 2.5 reported here. The reported statistical significance (p-values) of these features underscores their diagnostic value, consistent with guidelines from authoritative bodies like the American Thyroid Association (ATA) Kobaly *et al.* [8]. Table 3 addresses the influence of radiologist experience and ultrasound equipment quality on the

Table 3: Impact of Radiologist Experience and Ultrasound Equipment Quality on the Diagnostic Accuracy of Ultrasound for Thyroid Nodules

Factor	No. of percentage	OR	95% CI	p-value
Radiologist Experience	High Experience (100)	1.5	1.1-2.0	0.02
Ultrasound Equipment Quality	High Quality (100)	2.0	1.4-2.8	0.01

diagnostic accuracy, suggesting that both factors significantly enhance the predictive power of ultrasound. These findings echo the conclusions of Saleem *et al*.[9] who emphasized the critical role of radiologist expertise in interpreting complex cases and improving diagnostic outcomes. Furthermore, the improvement associated with high-quality ultrasound equipment, as indicated by an OR of 2.0, reinforces the notion that technological advancements contribute to better detection and characterization of thyroid nodules, as discussed by Xie F *et al*.[10].

CONCLUSION

The cross-sectional analysis of the role of ultrasound in diagnosing thyroid nodules has elucidated the significant diagnostic value of this imaging modality. Our findings demonstrate that ultrasound exhibits a sensitivity of 60% and a specificity of 80% in distinguishing between benign and malignant thyroid nodules. These metrics underscore ultrasound's utility as a non-invasive, readily available and efficient tool for the initial evaluation and triage of patients presenting with thyroid nodules. Further analysis revealed that specific ultrasound features, including microcalcifications, irregular margins, taller-than-wide shape and hypoechogenicity, are strongly indicative of malignancy. The statistical significance of these features, as evidenced by their odds ratios and p-values, highlights their critical role in guiding clinical decision-making and prioritizing patients for biopsy or surgical intervention.

Moreover, our study has identified the impact of radiologist experience and ultrasound equipment quality on diagnostic accuracy. The enhanced diagnostic outcomes associated with high radiologist experience and high-quality equipment emphasize the importance of expertise and technological advancements in optimizing patient care. In conclusion, ultrasound serves as a cornerstone in the diagnostic pathway of thyroid nodules, offering a balance of sensitivity and specificity that aids in the effective stratification of cancer risk. The identification of key sonographic features associated with malignancy further refines its diagnostic capacity. However, the variability in diagnostic accuracy, influenced by radiologist experience and equipment quality, suggests areas for ongoing professional development and investment in state-of-the-art technology. Our findings advocate for the continued use of ultrasound in the clinical management of thyroid nodules, while also highlighting the need for standardized protocols and training to maximize its diagnostic potential.

Limitations of Study

- **Cross-Sectional Design:** The cross-sectional nature of this study limits our ability to infer causality or track changes over time. Longitudinal studies would be better suited to observe the progression of thyroid nodules and the potential impact of ultrasound findings on long-term outcomes
- **Sample Size and Selection Bias:** The study's findings are based on a sample of 200 patients, which, while informative, may not be representative of the broader population. Selection bias may also influence the results if the study population does not accurately reflect the diversity of patients with thyroid nodules, including variations in age, sex and ethnicity
- **Inter-Observer Variability:** Despite the standardized criteria for ultrasound evaluation, there is potential for inter-observer variability among radiologists. Differences in experience and subjective interpretation of ultrasound features could affect the diagnostic accuracy reported
- **Technological Variability:** The study might not fully account for the variability in ultrasound equipment quality across different clinical settings. Advances in ultrasound technology and differences in equipment calibration can significantly influence the sensitivity and specificity of thyroid nodule detection.
- **Lack of Correlation with Final Histopathological Diagnosis:** While the study evaluates the sensitivity and specificity of ultrasound, it does not always correlate findings with the gold standard of histopathological diagnosis from fine-needle aspiration biopsy or surgical resection. This correlation is crucial for validating the true diagnostic accuracy of ultrasound features indicative of malignancy.
- **Single-Center Study:** If the study was conducted in a single clinical setting, the findings might not be generalizable to other institutions or settings with different patient demographics or clinical practices.
- **Exclusion of other Diagnostic Modalities:** The study focuses solely on ultrasound, without considering the role of additional diagnostic tools such as thyroid function tests, CT scans or MRI, which could complement ultrasound findings and improve diagnostic accuracy.
- **Overemphasis on Certain Ultrasound Features:** While the study highlights specific ultrasound features associated with malignancy, it may overlook the importance of other less common or newly identified features that could also contribute to the accurate diagnosis of thyroid nodules.

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