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Original Research Article

Diagnostic Accuracy of Thyroid Doppler in Predicting Malignancy in Thyroid Nodules, Keeping Histopathology as Gold Standard

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Abstract: *Thyroid nodules are common clinical findings with varying etiologies, ranging from benign lesions to malignant tumors. Accurate preoperative evaluation is crucial to avoid unnecessary surgeries. Doppler ultrasonography offers a non-invasive modality for assessing vascular characteristics associated with malignancy. However, its diagnostic performance varies across clinical settings.* ***Objective:*** *To evaluate the diagnostic accuracy of Doppler ultrasonography in detecting malignancy in thyroid nodules, using histopathological examination as the gold standard.* ***Methods:*** *This prospective observational study was conducted at KRL Hospital, Islamabad, from December 15, 2024, to March 15, 2025. Ethical approval was obtained from the Institutional Review Board. 150 patients (aged >18 years, both genders) with thyroid nodules identified clinically or through routine imaging were enrolled using non-probability consecutive sampling. Doppler ultrasonography was performed for all participants, followed by histopathological evaluation after surgical excision or fine-needle aspiration. Statistical analysis was carried out using SPSS v25. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), diagnostic accuracy, and receiver operating characteristic (ROC) curves were calculated for both modalities.* ***Results:*** *Doppler ultrasonography demonstrated a sensitivity of 82.6%, specificity of 77.3%, and an overall diagnostic accuracy of 80% in identifying malignant thyroid nodules. In comparison, histopathology revealed superior diagnostic metrics with a sensitivity of 97.06%, specificity of 90.24%, PPV of 89.19%, NPV of 97.37%, and diagnostic accuracy of 93%. The ROC curve analysis for histopathology confirmed high diagnostic performance with an AUC of 0.937.* ***Conclusion:*** *Doppler ultrasonography is a valuable, moderately accurate, and non-invasive diagnostic tool for assessing malignancy in thyroid nodules. Despite its moderate sensitivity and specificity, it remains a practical initial imaging modality, though histopathology remains the definitive diagnostic standard.*

Keywords: Thyroid nodules, Doppler, histopathology, accuracy

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Introduction

Prevalence of thyroid nodules is increasing globally with widespread use of diagnostic imaging (1). Most nodules are benign; however, approximately 5–15% of nodules are malignant, and therefore, accurate differentiation between benign and malignant is an important aspect of treatment (2). Despite being non-invasive, widely available and capable of assessing vascular patterns, Doppler ultrasonography has become a valuable tool for assessing thyroid nodules (3). Doppler imaging combined with gray-scale ultrasound help determine which nodules are suspicious due to examination of blood flow patterns suggesting malignancy (4). For confirmation, fine needle aspiration (FNAB) or surgical excision is often preceded by histopathology, which is the gold standard for definitive diagnosis (5). Precise diagnostic tools are critical since there is a need to avoid unnecessary surgeries for benign conditions, which cost the healthcare system and patient's morbidity. Unlike delayed treatment of malignant nodules may result in poor outcomes (6). Diagnostic accuracy of Doppler ultrasound to predict thyroid malignancy based on histopathology is critical in assessing whether Doppler ultrasound is accurate and ultimately improves patient care (7). Shahzad et al. (2023) study reported a sensitivity of 86.4% and specificity of 97.4 with 95.4% diagnostic accuracy in identifying malignancy. Doppler ultrasound produces increased vascularity, chaotic blood flow and central vascular patterns, which are commonly thought to be associated with malignancy, which are used to differentiate benign from malignant nodules (8). The utility of Doppler imaging is also supported by meta-analyses, with pooled sensitivities and specificities of 71 and 77 per cent, respectively and AUC of 0.917 (9). However, Doppler ultrasound has limitations, including operator dependency, and reduced performance when nodules are small or deeply located (10). However, when integrated with FNAB and other clinical factors, it improves diagnostic work flow, reducing needless interventions while allowing for prompt therapy for malignancy (11). Taken together, these findings underscore the need for Doppler ultrasound to become part of routine thyroid nodule evaluation, both prospectively to enhance patient outcomes. The present study aims to evaluate the diagnostic accuracy of Doppler Ultrasonography for predicting malignancy in thyroid nodules based on histopathology as the gold standard. The performance of key metrics (sensitivity, specificity, and overall diagnostic reliability) was assessed in the study.

Methodology

After the ethical approval from the institutional review board, this prospective observational study was conducted at KRL hospital, Islamabad, from 15-December-2024 to 15-March-2025. Through non-probability consecutive sampling, 150 patients aged above 18, both genders, with thyroid nodules revealed on clinical examination or routine imaging, were included in the present study. Patients with a pre-existing history of thyroid surgery, patients on thyroid-specific treatment, and patients with a contraindication to biopsy were excluded from the present study. After informed consent from the recruited patients, a high-resolution Doppler ultrasound machine was used for a comprehensive ultrasound evaluation of the patients. Evaluated key parameters were the size, shape, margins, echogenicity, and vascular patterns. A criteria-based Doppler, namely increased central vascularity, chaotic blood flow, and irregular vascular architecture indicative of malignancy, was used to categorize Doppler findings as "Malignant" or "Benign". Gray-scale ultrasound findings were also documented for an overall analysis. FNAB

was performed on all nodules to obtain cytological samples after performing the Doppler ultrasound. In cases where the FNAB was inconclusive, surgical excision was performed, and histopathological examination of the resected specimen was used as the definitive diagnosis. Histopathology results were classified as either 'Malignant' or 'Benign', and these results were considered as the gold standard for assessing the accuracy of Doppler ultrasound results. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy of Doppler ultrasonography were calculated based on comparison with histopathology. Statistical analysis was done with SPSS version 26, and Significance was determined with $p < 0.05$.

Results

The study included 150 patients with a mean age of 49.04 ± 18.2 years (Table 1). The majority of participants were male (62%, n = 93), while females comprised 38% (n = 57). The mean nodule size was 3.3 ± 1.6 cm, highlighting variability in the size of thyroid nodules evaluated in the study.

The diagnostic performance of Doppler ultrasonography was analyzed, as shown in Table 2. Out of 74 nodules identified as malignant by Doppler ultrasound, 57 were confirmed malignant and 17 were benign. Of the 71 nodules identified as benign, 12 were later confirmed malignant, while 59 were benign. This yielded a sensitivity of 82.6%, a specificity of 77.3%, and an overall diagnostic accuracy of 80%. The positive predictive value (PPV) and negative predictive value (NPV) were 77.3% and 83.1%, respectively. The Receiver Operating Characteristic (ROC) curve analysis for Doppler ultrasonography (Figure 1) illustrated moderate diagnostic accuracy (AUC=0.765).

In contrast, histopathology, as the gold standard, demonstrated superior diagnostic performance (Table 3). Of the 74 nodules classified as malignant by histopathology, 66 were correctly identified as malignant, while 8 were benign. Among 76 nodules classified as benign, only 2 were confirmed malignant, while 74 were benign. This resulted in a sensitivity of 97.06% and a specificity of 90.24%, with an overall diagnostic accuracy of 93%. The PPV and NPV were 89.19% and 97.37%, respectively. The ROC curve for histopathology (Figure 2) confirmed its high diagnostic accuracy (AUC=0.937).

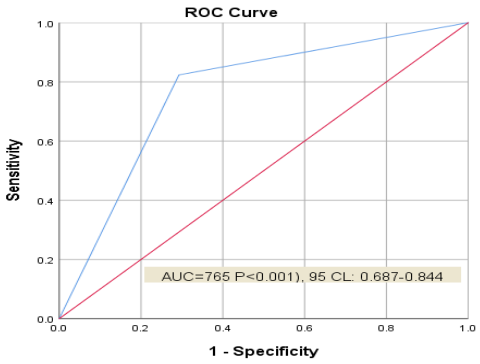

Figure 1: ROC Curve analysis of Doppler

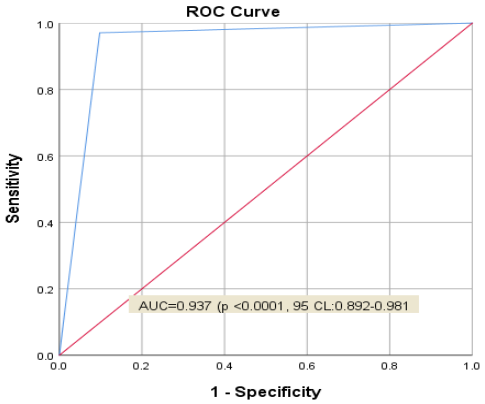

Figure 2: ROC curve analysis of Histopathology.

Table 1: Demographic and clinical variables

Variables	Mean and Frequency
Age (years)	49.04±18.2
Gender	
Male	93 (62%)
Female	57 (38%)
Nodule size	3.3±1.6

Table 2: Sensitivity and specificity analysis of Doppler results

Doppler Result	Diagnosis		Total
	Malignant	Benign	
Malignant	57	17	74
Benign	12	59	71
Total	69	76	150
Sensitivity	82.60%		
Specificity	77.30%		
Accuracy	80%		
PPV	77.30%		
NPV	83.10%		

Table 3: Sensitivity and specificity analysis of Histopathology results

Histopathology	Diagnosis		Total
	Malignant	Benign	
Malignant	66	8	74
Benign	2	74	76
Total	68	82	150
Sensitivity	97.06%		

Specificity	90.24%
Accuracy	93%
PPV	89.19%
NPV	97.37%

Discussion

This study validates previous research on the diagnostic capability of Doppler ultrasonography when used for thyroid nodule assessments. These diagnostic results match those reported in earlier publications. A meta-analysis presented data indicating high diagnostic accuracy through pooled sensitivity at 71% and specificity at 77% and an area under the curve (AUC) of 0.917 (9). The research of Shahzad et al. (2022) showed Doppler ultrasonography reached a 86.4% sensitivity along with a 97.4% specificity for diagnosing malignant thyroid nodules and a 95.4% diagnostic accuracy (8). The differences in diagnostic metrics between studies stem from variations in study design together with sample size and operator expertise. The ROC curve statistics from the current study showed that Doppler ultrasonography achieved moderate levels of accuracy with an AUC value of 0.765. These findings represent an AUC value that is slightly below what the previous meta-analysis produced possibly because of sample-related or methodological reasons (12). Histopathological examination continues to serve as the definitive diagnostic method for thyroid malignancies because it demonstrates a superior sensitivity of 97.06% and specificity of 90.24% in this study series (13). Histopathological examination represents the essential tool which confirms malignancy while maintaining Doppler ultrasonography as a valuable diagnostic screening method (14). Studies show that Doppler ultrasonography stands as a vital non-invasive tool for thyroid nodule assessment yet demonstrates assorted diagnostic abilities. Definitive diagnosis depends on histopathological examination even though it maintains its essential role (15). Using Doppler ultrasound data together with additional diagnostic tools and clinical records will help improve diagnostic precision while improving patient treatment approaches.

Conclusion

Doppler ultrasonography works as a dependable tool for thyroid nodule assessment because it shows moderate accuracy through testing evidence that includes 82.6% sensitivity and 77.3% specificity. The diagnosis of thyroid disease relies primarily on histopathology because it provides excellent accuracy at 97.06% sensitivity and 90.24% specificity. Doppler results integrated alongside histopathology and clinical testing enhance both diagnostic accuracy and patient treatment results.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval and consent to participate
Approved by the department concerned. (IRBEC-KRLISB-98-24)
Consent for publication
Approved
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Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

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All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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