MEDS Clinical Medicine (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/medsc.2025.060408
ISSN 2616-1907 Vol. 6 Num. 4

A Study on Diagnostic Approaches for Thyroid Nodules Using Ultrasound Imaging

Lina Shang

The Affiliated Hospital of Hebei University, Baoding, Hebei, China

Keywords: Ultrasound imaging, Thyroid nodules, Diagnostic accuracy

Abstract: The Objective is to assess the clinical value of ultrasound imaging in diagnosing thyroid nodules and to furnish evidence for facilitating efficient, non-invasive clinical diagnosis. Eighty patients with thyroid nodules admitted between January 2024 and December 2024 were consecutively enrolled in this study. All participants underwent both ultrasound imaging and pathological confirmation. Using pathological findings as the gold standard, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of ultrasound were computed. For ultrasound diagnosis of thyroid nodules, the sensitivity, specificity, diagnostic accuracy, PPV, and NPV were 88.9%, 85.7%, 87.5%, 82.4%, and 91.3%, respectively. Malignant nodules predominantly presented with hypoechogenicity, ill-defined boundaries, microcalcifications, and abundant vascularity, whereas benign nodules were primarily characterized by hyperechogenicity, well-defined boundaries, and an absence of calcifications. Ultrasound imaging exhibits substantial diagnostic value in differentiating between benign and malignant thyroid nodules and thus serves as the first-line non-invasive diagnostic modality in clinical practice. A comprehensive assessment integrating clinicians' expertise with other diagnostic approaches is warranted to enhance diagnostic accuracy.

1. Introduction

Thyroid nodules rank among the prevalent conditions of the endocrine system, with their incidence rising markedly alongside the widespread adoption of ultrasound examination techniques. Epidemiological data indicate that the detection rate of thyroid nodules in the general population ranges from 20% to 76%, with approximately 5% to 15% being malignant lesions. Within traditional diagnostic paradigms, fine-needle aspiration biopsy (FNAB) is recognized as the gold standard for diagnosis; nonetheless, its invasiveness, operator dependence, and risk of false negatives have limited its clinical application. Ultrasound imaging, with advantages of non-invasiveness, real-time capability, and repeatability, has emerged as a cornerstone tool for screening and diagnosing thyroid nodules[1]. Recent advances in high-resolution ultrasound equipment and novel techniques (e.g., contrast-enhanced ultrasound, elastography) have substantially enhanced the sensitivity and specificity of ultrasound for thyroid nodule diagnosis. Studies have demonstrated that experienced sonographers integrating typical sonographic features achieve a diagnostic accuracy exceeding 85% for malignant nodules. Notably, thyroid nodules exhibit marked ultrasonic heterogeneity: some benign nodules may display malignant-like characteristics, while early-stage papillary carcinoma can present as isoechoic or hyperechoic lesions. Consequently, establishing a more systematic evaluation framework with focused analysis of ultrasonic features is imperative[2]. This study aims to assess the clinical value of ultrasound imaging in the diagnosis of thyroid nodules and furnish evidence to facilitate efficient, non-invasive clinical diagnosis.

2. Materials and Methods

2.1. General Data

Eighty patients with thyroid nodules admitted between January 2024 and December 2024 were consecutively enrolled. Among them, 23 were male (28.8%) and 57 were female (71.2%), aged 22 to 75 years with a mean of (46.3 ±11.8) years; the disease duration ranged from 3 months to 12 years, with an average of (2.6 ±1.9) years.

The inclusion criteria were as follows: (1) patients with thyroid nodules confirmed by pathological examination; (2) those with clear ultrasound image quality; and (3) those with complete clinical data. The exclusion criteria were as follows: (1) patients with concurrent other thyroid diseases; (2) those with a previous history of thyroid surgery, radiotherapy, or chemotherapy; (3) pregnant or lactating women; and (4) those with poor-quality images or incomplete clinical data. All enrolled patients provided written informed consent, and the study was approved by the hospital's ethics committee.

2.2. Methods

Prior to the examination, patients were positioned in a supine posture with their necks fully exposed. The examining physician evenly applied a suitable amount of coupling gel to the cervical skin to minimize acoustic wave transmission interference. A Philips EPIQ 7 color Doppler ultrasound system was utilized, equipped with a high-frequency linear array transducer (frequency range: 7.5–12 MHz). The transducer was maintained in close contact with the skin, with care taken to avoid excessive pressure. During the examination, initial assessments were based on transverse and longitudinal views of the thyroid, with a comprehensive evaluation of bilateral thyroid morphology, size, and internal echogenicity. Subsequent focus was directed to nodule regions, documenting parameters including nodule count, location, maximum diameter, border definition, internal echogenic features, presence of microcalcifications or macrocalcifications, and posterior echo attenuation. Color Doppler flow imaging was employed to assess the degree of vascularity within and around nodules. The entire examination was performed independently by two physicians; in cases of discrepant nodule characterization, consensus was achieved through joint review of dynamic images and deliberation on subtle variations in nodule morphology and blood flow distribution, thereby ensuring diagnostic objectivity and accuracy.

2.3. Observation Indicators

Using pathological findings as the gold standard, the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic accuracy of ultrasound were computed.

2.4. Statistical Analysis

Statistical analyses were performed using SPSS 22.0 software. Categorical data were presented as percentages and analyzed via the chi-square (x^2) test, while continuous data were expressed as (mean ± standard deviation) and analyzed using the t-test. A P-value < 0.05 was considered a statistically significant difference.

3. Results

Ultrasound diagnosis of thyroid nodules yielded a sensitivity of 88.9%, specificity of 85.7%, accuracy of 87.5%, positive predictive value (PPV) of 82.4%, and negative predictive value (NPV) of 91.3%. Malignant nodules predominantly exhibited hypoechogenicity, ill-defined boundaries, microcalcifications, and increased vascularity, whereas benign nodules were characterized primarily by hyperechogenicity, well-defined boundaries, and an absence of calcifications. Receiver operating characteristic (ROC) curve analysis demonstrated that the area under the curve (AUC) for ultrasound diagnosis was 0.912 (95% confidence interval [CI]: 0.834-0.990), reflecting robust diagnostic performance (Table 1).

Table 1 Comparison of ultrasound diagnostic efficacy and pathological findings in 80 patients with thyroid nodules.

Indicator	Value (%)	95% Confidence Interval
Sensitivity	88.9	77.4～96.1
Specificity	85.7	73.8～93.9
Accuracy	87.5	78.4～94.1
Positive Predictive Value (PPV)	82.4	69.5～91.8
Negative Predictive Value (NPV)	91.3	81.0～97.1
Area Under ROC Curve (AUC)	0.912	0.834～0.990

4. Discussion

Thyroid nodules represent clinically prevalent thyroid conditions, with their diagnosis hinging on medical history collection, physical examination, laboratory assays, and imaging studies. Among these modalities, ultrasound has emerged as the first-line approach for screening and diagnosing thyroid nodules, attributable to its non-invasiveness, accessibility, and excellent repeatability. For suspected malignant nodules, fine-needle aspiration biopsy (FNAB) furnishes cytological diagnostic evidence; nonetheless, its invasiveness limits its clinical application. Accordingly, enhancing the diagnostic accuracy of non-invasive examinations and minimizing unnecessary invasive procedures constitute critical research directions in the diagnosis and treatment of thyroid nodules[3]. The results of this study demonstrate that ultrasound imaging exhibits robust diagnostic efficacy in differentiating benign from malignant thyroid nodules, with high levels of sensitivity, specificity, accuracy, PPV, and NPV. This underscores that as a non-invasive, accessible, and reproducible imaging modality, ultrasound imaging holds substantial utility in the screening and preliminary diagnosis of thyroid nodules. In contrast to FNAB, ultrasound examination obviates the need for puncture, thereby avoiding complications like bleeding and infection—an advantage that renders it particularly suitable for high-risk patients or those intolerant of invasive procedures. Ultrasound enables real-time assessment of nodule size, morphology, boundaries, internal echogenicity, and vascularity, yielding extensive diagnostic information. Furthermore, its ease of operation and capacity for multiple follow-ups facilitate dynamic surveillance of nodule changes, making it especially valuable for thyroid nodule screening and postoperative follow-up. The accuracy of ultrasound diagnosis is influenced by multiple factors: ultrasound device resolution, operator expertise, and intrinsic sonographic characteristics of the nodules. Certain benign nodules may be misclassified as malignant owing to calcifications or irregular morphology, whereas early-stage malignant nodules may be subject to missed diagnosis due to homogeneous echogenicity and well-defined boundaries. Consequently, exclusive reliance on ultrasound diagnosis entails inherent limitations, necessitating comprehensive evaluation integrating clinical data, laboratory assays, and other imaging modalities[4]. The present study revealed that malignant nodules predominantly exhibit hypoechogenicity, ill-defined boundaries, microcalcifications, and increased vascularity, whereas benign nodules are characterized primarily by hyperechogenicity, well-defined margins, and an absence of calcifications. Owing to their high cellular density and sparse stromal components, malignant nodules typically display hypoechogenicity or marked hypoechogenicity, creating a distinct contrast with adjacent normal thyroid tissue. Malignant nodules often exhibit invasive growth, presenting with ill-defined or spiculated boundaries on ultrasound. In contrast, benign nodules are mostly round or oval with well-defined margins. Microcalcifications—a typical feature of thyroid papillary carcinoma—are linked to mucus or colloid secretion by tumor cells. Macrocalcifications are more prevalent in benign nodules. Given their rapid growth, malignant nodules frequently exhibit increased vascularity, particularly disorganized vascularity in both peripheral and internal regions. Benign nodules, which contain abundant colloid or fibrous components, typically display hyperechogenicity or isoechogenicity, with regular morphology, well-defined boundaries, and distinct demarcation from adjacent tissues. Microcalcifications are infrequent in benign nodules; when present, they are generally coarse and solitary. Benign nodules typically demonstrate weak vascular signals, manifesting as peripheral flow or avascularity. While these ultrasonic features possess diagnostic value, some nodules may exhibit overlapping benign and malignant features. In such instances, a comprehensive assessment integrating clinical data and additional examinations is warranted to enhance diagnostic accuracy[5].

In conclusion, ultrasound imaging holds substantial diagnostic value in differentiating benign from malignant thyroid nodules. Its non-invasiveness, accessibility, and reproducibility render it the first-line preliminary diagnostic modality in clinical practice.

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