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Application of Grayscale Contrast-Enhanced Ultrasonography in the Diagnosis of Thyroid Nodules

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Abstract: The Objective is to investigate the application value of grayscale contrast-enhanced ultrasonography in the diagnosis of thyroid nodules. Sixty patients with suspected thyroid nodules, admitted between January 2024 and January 2025, were randomized into two groups: the control group and the study group. The control group (n=30) underwent conventional ultrasonography, whereas the study group (n=30) received grayscale contrast-enhanced ultrasonography. With postoperative pathology or fine-needle aspiration biopsy as the gold standard, we compared the sensitivity, specificity, accuracy, and consistency of the two diagnostic modalities. The diagnostic performance of the study group in differentiating benign from malignant thyroid nodules was significantly superior to that of the control group. Grayscale contrast-enhanced ultrasonography demonstrated higher sensitivity, specificity, and accuracy compared with conventional ultrasonography. Kappa test results indicated that the agreement between grayscale contrast-enhanced ultrasonography and pathological diagnosis was significantly higher than that between conventional ultrasonography and pathological diagnosis ($P<0.05$). Grayscale contrast-enhanced ultrasonography significantly enhances the diagnostic accuracy of thyroid nodules, particularly exhibiting high sensitivity and specificity in distinguishing benign from malignant lesions. It offers more robust diagnostic evidence for clinical practice and holds substantial clinical application value.

1. Introduction

Thyroid nodules rank among the clinically common thyroid disorders. Epidemiological data indicate that the detection rate of thyroid nodules in the general population ranges from 20% to 76%, the majority of which are benign; nevertheless, 5% to 15% are potentially malignant. Accurate differentiation of benign versus malignant thyroid nodules is of great significance for formulating reasonable treatment protocols and preventing unnecessary surgical interventions[1]. The diagnosis of thyroid nodules is predominantly reliant on imaging examinations, with ultrasonography emerging as the first-line screening and diagnostic tool owing to its advantages of non-invasiveness, accessibility, and high reproducibility. Conventional ultrasonography affords insights into characteristics including nodule size, shape, boundary, echogenicity, and vascularity, endowing it with modest utility in differentiating benign from malignant nodules. Nonetheless, conventional ultrasonography exhibits constraints when assessing small lesions, hypoechoic nodules, or those with complex internal structures, being susceptible to factors like operator expertise and image resolution—thereby compromising its diagnostic efficacy. In recent years, contrast-enhanced ultrasound has emerged as an innovative imaging modality, with grayscale contrast-enhanced ultrasonography—a subset thereof—enabling more precise visualization of lesions' fine structures and hemodynamic changes, thereby facilitating a further enhancement in the diagnostic accuracy of thyroid nodules[2]. This study aims to investigate the application value of grayscale contrast-enhanced ultrasound in the diagnosis of thyroid nodules.

2. Materials and Methods

2.1. General Data

Sixty patients with suspected thyroid nodules, admitted between January 2024 and January 2025, were randomized into two groups: the control group and the study group. The control group comprised 12 males (40%) and 18 females (60%), aged 22–68 years with a mean age of (43.5±8.2) years. The study group included 11 males (36.7%) and 19 females (63.3%), aged 21–67 years with a mean age of (42.8±7.9) years. No statistically significant differences were observed in terms of gender distribution or age between the two groups ($P>0.05$). All patients presented with manifestations such as neck masses, dysphagia, or abnormal thyroid echoes identified on physical examination. The inclusion criteria were as follows: Patients with suspected thyroid nodules based on preliminary clinical evaluation, who voluntarily consented to undergo ultrasound examinations and comply with subsequent pathological verification. The exclusion criteria were as follows: Patients with a history of thyroid surgery, severe comorbid cardiopulmonary diseases, or a known allergy to contrast agents.

2.2. Methods

Patients in the control group underwent conventional ultrasonography: conducted by experienced sonographers adhering to standardized operating procedures. Prior to the procedure, physicians elicited a detailed medical history, including the duration of neck discomfort and characteristics of mass evolution, and apprised patients of precautionary measures. Patients were positioned supine with the neck fully exposed, and shoulders elevated to fully extend the thyroid region. A high-frequency linear probe (7.5–12 MHz) was utilized. Initially, two-dimensional ultrasonographic scanning was performed in transverse and longitudinal planes of the thyroid to systematically assess nodule location, number, size, morphology, boundary, internal echogenicity, and relationship with adjacent tissues. Subsequently, the modality was switched to color Doppler flow imaging to dynamically evaluate vascular distribution within and around nodules, with emphasis on documenting blood flow signal intensity, direction, and hemodynamic parameters such as resistance index. Throughout the procedure, probe angle and gain settings were adjusted in real time to ensure clear visualization of the entire nodule. Representative sectional images and measurements were concurrently recorded, and a comprehensive diagnosis was formulated by integrating two-dimensional morphologic features with hemodynamic findings. The total examination duration was approximately 10–15 min.

Patients in the study group underwent grayscale contrast-enhanced ultrasonography, performed collaboratively by a team of sonographers. Prior to the procedure, physicians reconfirmed the absence of contrast agent allergy, elucidated the contrast protocol and potential mild warmth sensation, and positioned patients in a comfortable supine posture with shoulders elevated to fully extend the neck. For contrast enhancement, an ultrasound diagnostic system equipped with contrast-specific analytical software was utilized. The contrast agent (sulfur hexafluoride microbubble formulation) was administered as a rapid bolus via the cubital vein, with dosage calculated by body weight (typically 1.2–2.4 mL), immediately followed by a 5-mL saline flush. Real-time contrast mode was initiated concurrently with injection, and the probe frequency was adjusted to 3–6 MHz to optimize contrast signals. Physicians continuously and dynamically monitored thyroid nodule perfusion, with focused documentation of enhancement onset time, intensity, uniformity, washout rate, and presence of centripetal or centrifugal perfusion. Concurrently, the system was rapidly switched to low mechanical index mode to minimize microbubble destruction. The entire contrast phase lasted 3–5 min, during which physicians adjusted the probe angle as needed to capture perfusion characteristics across different nodule planes, with dynamic imaging data saved in real time. Post-procedure, physicians actively queried patients for discomfort, and patients were permitted to leave the examination room only after confirming no adverse reactions. The total duration was approximately 20–25 min.

2.3. Observation Indicators and Evaluation Criteria

Postoperative pathology or fine-needle aspiration biopsy findings served as the gold standard for determining the accuracy of ultrasound diagnoses. Sensitivity was defined as the proportion of malignant nodules correctly identified by ultrasonography; specificity was the ability of ultrasonography to correctly rule out malignant nodules; accuracy referred to the proportion of cases where ultrasound diagnosis findings were completely consistent with pathological diagnosis findings among the total number of cases. To quantify the agreement between grayscale contrast-enhanced ultrasonography and pathological diagnosis, the Kappa test was employed. The closer the Kappa value is to 1, the stronger the agreement between grayscale contrast-enhanced ultrasonography and pathological diagnosis[3].

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; 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

Table 1 Comparison of Diagnostic Outcomes Between the Two Groups.

Indicator	Study group	Control group	Statistical Value	P value
Diagnostic sensitivity (%)	86.7 (26/30)	66.7 (20/30)	4.300	<0.05
Diagnostic specificity (%)	90 (27/30)	73.3 (22/30)	2.770	<0.05
Diagnostic accuracy (%)	93.3 (28/30)	70 (21/30)	6.430	<0.05
Kappa value	0.85	0.42	-	<0.05

The study group demonstrated significantly superior diagnostic efficacy in distinguishing benign from malignant thyroid nodules compared with the control group. Grayscale contrast-enhanced ultrasonography exhibited higher sensitivity, specificity, and accuracy relative to conventional ultrasonography. Kappa test results indicated that the agreement between grayscale contrast-enhanced ultrasonography and pathological diagnosis was significantly higher than that between conventional ultrasonography and pathological diagnosis ($P<0.05$), as shown in Table 1.

4. Discussion

Thyroid nodules are localized masses within the thyroid that can move up and down with swallowing. They are highly prevalent in the general population. Clinically, most thyroid nodules are benign, and patients may be asymptomatic, often detected incidentally during physical examinations or workups for other conditions. However, some nodules can impair thyroid function, causing symptoms of hyperthyroidism or hypothyroidism, while a small proportion of malignant nodules may invade adjacent tissues or metastasize. The etiology of thyroid nodules is not fully elucidated, with associations to multiple factors including abnormal iodine intake, autoimmune diseases, radiation exposure, and genetic predisposition. With the wider adoption of ultrasonography, the detection rate of thyroid nodules has increased markedly, yet accurately distinguishing benign from malignant lesions remains a critical clinical challenge[4]. The findings of this study demonstrated that grayscale contrast-enhanced ultrasonography exhibited significantly superior diagnostic efficacy in distinguishing benign from malignant nodules compared with conventional ultrasonography, with marked improvements in sensitivity, specificity, and accuracy, as well as stronger agreement with pathological diagnoses ($P<0.05$). Distinguishing between benign and malignant thyroid nodules has long been a challenge in clinical imaging. While conventional ultrasonography can provide features such as nodule size, morphology, boundary, echogenicity, and vascularity, it may fail to yield definitive diagnoses for nodules with overlapping characteristics when used in isolation. Grayscale contrast-enhanced ultrasonography, via microbubble contrast agents, significantly enhances the visualization of blood perfusion signals, thereby clarifying the microvascular architecture within lesions. Malignant thyroid nodules typically exhibit vascular features such as rapid enhancement, heterogeneous perfusion, or rapid wash-in and wash-out, whereas benign nodules commonly demonstrate slow enhancement or homogeneous perfusion. This hemodynamic discrepancy confers grayscale contrast-enhanced ultrasonography with higher sensitivity and specificity in differentiating benign from malignant nodules[5].

In conclusion, grayscale contrast-enhanced ultrasonography holds significant clinical application value in the diagnosis of thyroid nodules. It is expected to serve as a valuable adjunct to conventional ultrasonography, providing new impetus for the precise diagnosis and management of thyroid disorders.

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