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Detection Rate and Characteristic Analysis of Color Doppler Ultrasound for Papillary Thyroid Microcarcinoma

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Abstract: *Objective*: To investigate the detection rate and sonographic characteristics of color Doppler ultrasound in the diagnosis of papillary thyroid microcarcinoma (PTMC). *Methods*: A retrospective analysis was conducted on 50 cases of PTMC confirmed by postoperative pathology from January 2020 to December 2024, all of which underwent preoperative color Doppler ultrasound examination. The detection rate was calculated, and the two-dimensional ultrasound characteristics and CDFI manifestations were analyzed. *Results*: Among the 50 cases of PTMC confirmed by pathology, the detection rate of color Doppler ultrasound was 88.00%, and the diagnostic accuracy rate was 96.00%. Two-dimensional ultrasound characteristics: The mean lesion size was (6.83 ± 1.51) mm; 42 cases (84.00%) had irregular shapes; 45 cases (90.00%) had unclear boundaries; 46 cases (92.00%) had hypoechoic lesions; 38 cases (76.00%) exhibited microcalcifications; and 40 cases (80.00%) had an aspect ratio ≥ 1. CDFI characteristics: The highest proportion was grade II, with 23 cases (46.00%); 39 cases (78.00%) had an RI ≥ 0.7, and the average RI value was (0.75 ± 0.06). *Conclusion*: Color Doppler ultrasound demonstrates a high detection rate for PTMC, with typical features including hypoechogenicity, irregular shape, microcalcifications, and high RI, making it the preferred imaging modality for early clinical diagnosis of PTMC.

Keywords: Color Doppler ultrasound; Papillary thyroid microcarcinoma; Detection rate; Ultrasonic features

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1. Introduction

Thyroid cancer is the most prevalent malignant tumor in the endocrine system, with papillary carcinoma accounting for the highest proportion. Papillary thyroid microcarcinoma (PTMC), a specific subtype of papillary carcinoma, is defined as papillary thyroid carcinoma with a maximum lesion diameter of ≤ 10 mm. It is characterized by relatively slow growth and a lower degree of malignancy [1]. However, some patients may experience lymph node metastasis in the early stages, which can significantly impact their prognosis. Due to the extremely small size of the lesions, conventional palpation is prone to missed diagnoses, making imaging exploration a crucial window for detecting lesions. High-frequency color Doppler ultrasound, relying on its non-invasive, cost-effective, and repeatable advantages, has become the primary tool for evaluating thyroid nodules [2]. Its grayscale imaging can analyze morphological indicators such as nodule margins, echogenicity, and microcalcifications, while CDFI can further depict blood flow distribution and resistance parameters, providing quantitative evidence for determining whether a nodule is benign or malignant [3]. In recent years, there have been a relatively large number of studies on the diagnosis of papillary thyroid microcarcinoma (PTMC) using color Doppler ultrasound. However, variations in sample sizes, instrumentation, and diagnostic criteria across different studies have led to inconsistent reports on detection rates. Based on this, this study included 50 patients with PTMC who were admitted and treated, systematically analyzing the detection rate and characteristic manifestations of color Doppler ultrasound to clarify its diagnostic value. The specific content is as follows.

2. Materials and methods

2.1. General information

A retrospective analysis was conducted on 50 cases pathologically confirmed from January 2020 to December 2024. Gender distribution: 12 males and 38 females; age range: 28 to 65 years, with a mean age of (45.6 ± 8.21) years; the interval from discovery to surgery ranged from 1 to 12 months, with an average of (5.3 ± 2.14) months. Three patients sought medical attention due to palpable neck lymphadenopathy, while the remaining 47 cases were further evaluated after thyroid nodules were detected by ultrasound during routine health check-ups.

2.1.1. Inclusion criteria

(1) Histologically confirmed PTMC with a maximum lesion diameter ≤ 10 mm postoperatively [4]
(2) Color Doppler ultrasound examination conducted within 7 days before surgery, with complete data and images
(3) No prior history of thyroid surgery, radiation, or chemotherapy
(4) No history of concurrent malignant tumors

2.1.2. Exclusion criteria

(1) Missing ultrasound records or poor image quality that prevented interpretation
(2) Significant thyroiditis (such as active Hashimoto's disease) that limited imaging assessment
(3) Pregnancy or lactation

2.2. Methods

The examinees were not required to fast and were placed in a supine position with their heads and necks hyperextended. A soft pillow could be placed under their shoulders to fully expose the anterior cervical region. The Philips IU22 color Doppler ultrasound diagnostic instrument was selected, with a probe frequency of 5–12 MHz. The scanning sequence included longitudinal, transverse, and oblique sections, systematically covering the bilateral glandular lobes and the isthmus. First, grayscale imaging was performed to record characteristics such as glandular volume, echo background, and the location, maximum diameter, shape (regular/irregular), margin (well-defined/ill-defined), internal echo (hyperechoic/isoechoic/hypoechoic/anechoic), presence of calcification (microcalcification/macrocalcification/no calcification), and aspect ratio (the ratio of the anteroposterior diameter to the transverse diameter of the lesion) of the target nodules. Subsequently, the mode was switched to CDFI, and the blood flow within and around the nodules was evaluated and graded according to the Adler method. Arterial sampling was performed within the lesion to measure the resistance index (RI). All images were independently interpreted by two physicians with ≥ 5 years of experience in thyroid ultrasound, and in cases of disagreement, a consensus was reached through discussion.

2.3. Observation indicators

Using surgical pathology results as the gold standard, the following indicators were observed and recorded

(1) The detection of PTMC by color Doppler ultrasound, calculating the detection rate (number of clearly diagnosed cases/total number of cases × 100%) and the diagnostic accuracy rate (number of clearly diagnosed cases + number of suspected cases/total number of cases × 100%)

(2) The two-dimensional ultrasound characteristics of PTMC, including the maximum diameter of the lesion, shape (regular/irregular), margin (clear/unclear), internal echo (hyperechoic/isoechoic/hypoechoic), calcification status (microcalcification/macrocalcification/ no calcification), and aspect ratio (≥ 1/< 1)

(3) The CDFI characteristics of PTMC, including the grading of blood flow signals (using the Adler blood flow grading standard) and the resistance index (RI) of arterial blood flow within the lesion, calculating the proportion of different blood flow grades and the proportion of cases with an RI ≥ 0.7.

2.4. Statistical methods

Comparisons were made using SPSS 23.0 software. Count data were expressed as percentages (%) and tested using the χ^2 test, while measurement data conforming to a normal distribution were expressed as mean ± standard deviation and tested using the *t*-test. A statistically significant difference was considered when $p < 0.05$.

3. Results

3.1. Detection rate of color Doppler ultrasound

Using surgical pathology results as the gold standard, among the 50 patients with PTMC, color Doppler ultrasound definitively diagnosed 44 cases as PTMC before surgery, suspected 4 cases of PTMC, and misdiagnosed 2 cases as benign nodules (nodular goiter). The ultrasound detection rate was 88.00% (44/50), and the diagnostic accuracy rate was 96.00% (48/50).

3.2. Two-dimensional ultrasound characteristics of PTMC

Analysis of two-dimensional sonograms: The maximum diameter of the lesions ranged from 3 to 10 mm, with a mean of (6.83 ± 1.51) mm; 18 cases (36.00%) had lesions ≤ 5 mm, and 32 cases (64.00%) had lesions > 5 mm; The primary signs, in order, were hypoechoic (92.00%), ill-defined borders (90.00%), an aspect ratio ≥ 1 (80.00%), irregular shape (84.00%), and microcalcifications (76.00%). See **Table 1** for details.

Table 1. Distribution of two-dimensional ultrasound characteristics (n, %)

Feature	Category	Number of cases (n)	Percentage (%)
Maximum diameter	≤ 5 mm	18	36.00
	5–10 mm	32	64.00
Shape	Irregular	42	84.00
	Regular	8	16.00
Boundary	Unclear	45	90.00
	Clear	5	10.00
Internal echo	Hypoechoic	46	92.00
	Isoechoic	4	8.00
Calcification	Microcalcification	38	76.00
	Macrocalcification	2	4.00
	No calcification	10	20.00
A/T ratio	≥ 1	40	80.00
	< 1	10	20.00

3.3. CDFI characteristics of PTMC

The CDFI examination results revealed that among the 50 cases of PTMC lesions, the majority of blood flow signal grading was Grade II (46.00%), followed by Grade I (24.00%), Grade III (20.00%), and Grade 0 (10.00%). The RI value measurements indicated that 39 cases (78.00%) had an RI ≥ 0.7, while 11 cases (22.00%) had an RI < 0.7, with an average RI value of (0.75 ± 0.06). See **Table 2** for details.

Table 2. Distribution of CDFI characteristics (n, %)

CDFI feature	Category	Number of cases (n)	Percentage (%)
Blood flow grade	Grade 0 (No flow)	5	10.00
	Grade I (Minimal)	12	24.00
	Grade II (Moderate)	23	46.00
	Grade III (Abundant)	10	20.00
Resistive index (RI)	≥ 0.7	39	78.00
	< 0.7	11	22.00

4. Discussion

Due to the small size of PTMC lesions, clinical palpation is often ineffective in detecting them. Traditional imaging examinations such as CT and MRI have relatively low resolution for small lesions, limiting their diagnostic value. Color Doppler ultrasound, leveraging the high resolution of its high-frequency probe, can clearly display the morphological characteristics and hemodynamic changes of thyroid microlesions, making it a crucial tool for the early diagnosis of PTMC [5]. The results of this study demonstrate that the detection rate of PTMC by color Doppler ultrasound is 88.00%, with a diagnostic accuracy rate of 96.00%, which is generally consistent with previous research findings [6]. Meanwhile, the two misdiagnosed cases in this study were both tiny lesions with diameters ≤ 5 mm, and they did not exhibit characteristic manifestations such as microcalcifications or an aspect ratio ≥ 1. Their ultrasound appearances were low-echoic nodules with relatively clear boundaries, making differentiation from benign nodules challenging. Therefore, for PTMC (Papillary Thyroid Microcarcinoma) with excessively small diameters and a lack of typical malignant features, ultrasound diagnosis still has certain limitations, necessitating the combination of other examination methods for a definitive diagnosis.

This study also found that PTMC exhibits typical two-dimensional ultrasound characteristics, with hypoechogenicity, ill-defined borders, irregular shapes, the presence of microcalcifications, and an aspect ratio ≥ 1 serving as primary diagnostic criteria. Among these, hypoechogenicity is the most common feature of PTMC. In this study, 92.00% of the lesions presented as hypoechoic, which is related to the pathological characteristics of PTMC, where tumor cells are densely arranged and have little interstitial tissue [7]. The infiltrative growth of tumor cells results in ill-defined lesion borders, with 90.00% of the lesions in this study having ill-defined borders, which is a key manifestation of PTMC's malignant characteristics. Irregular shapes and an aspect ratio ≥ 1 are also typical features of PTMC, with 84.00% and 80.00% of the lesions, respectively, exhibiting these characteristics in this study. This is associated with the infiltrative growth of tumor cells into surrounding tissues, causing the lesion shape to lose its regularity [8]. Meanwhile, microcalcification is one of the most specific ultrasonic features of PTMC, with 76.00% of the lesions in this study exhibiting microcalcification, which is associated with the formation of psammoma bodies within the tumor tissue. Psammoma bodies are characteristic pathological manifestations of PTMC, formed by the deposition of calcium secreted by tumor cells, and appear as punctate hyperechoic foci with a diameter ≤ 2 mm on ultrasound [9]. However, microcalcification is not a specific manifestation of PTMC, as some benign nodules such as nodular goiter may also exhibit microcalcification, albeit at a lower incidence. Therefore, when ultrasound detects a hypoechoic thyroid nodule accompanied by microcalcification, the possibility of PTMC should be highly suspected [10]. Furthermore, CDFI can reflect the hemodynamic changes of the lesion, providing important supplementary evidence for the diagnosis of PTMC. In this study, 46.00% of the lesions had a blood flow signal graded as Grade II, and 20.00% as Grade III, indicating that most PTMC lesions have moderate or higher blood flow signals, consistent with the pathological characteristic that tumor growth requires a rich blood supply. RI is an important indicator reflecting vascular resistance, and malignant tumors typically have higher RI values due to thickened vessel walls and narrowed lumens. In this study, 78.00% of the lesions had an RI ≥ 0.7, with an average RI value of (0.75 ± 0.06), which is basically consistent with the average RI value (0.74 ± 0.20) in PTMC patients reported by Chen Yongcheng et al., further confirming that a high resistance index is an important blood flow characteristic of PTMC [11]. However, some benign nodules, such as thyroid adenomas, may also exhibit abundant blood flow signals, while some papillary thyroid microcarcinomas (PTMCs) may show inconspicuous blood flow signals due to their small lesion size. Therefore, the benign or malignant nature of a lesion cannot be solely determined based on the grading of blood flow signals; a comprehensive analysis incorporating two-dimensional ultrasound features is necessary [12].

5. Conclusion

In summary, color Doppler ultrasound demonstrates high detection and diagnostic accuracy rates for papillary thyroid microcarcinoma, with characteristic manifestations including hypoechogenicity, irregular shape, ill-defined margins, the presence of microcalcifications, and an aspect ratio of ≥ 1. CDFI typically reveals moderate to high blood flow signals and a high resistance index (RI ≥ 0.7). This method is non-invasive, quick to perform, and repeatable, making it suitable as a preliminary screening tool. In cases where the lesion diameter is extremely small or the signs are atypical, it is advisable to supplement with elastography, contrast imaging, or fine-needle aspiration to further reduce the risk of missed diagnoses.

Disclosure statement

The authors declare no conflict of interest.

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