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Research article

Dual concentric echo sign of ultrasound in primary hyperparathyroidism: The clinical and histopathologic features and differentiation from lymph nodes

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ABSTRACT

Context: Ultrasound (US) is the most economical and widely used method for detecting lesions in parathyroid regions. Identifying typically parathyroid adenomas as hypoechoic nodules with clear margins. However, 10 % of lesions exhibit atypical features, such as the dual concentric sign, and the cognition of them still needs to be improved.

Objective: To promote understanding of clinical and histopathological features for parathyroid lesions with the dual concentric echo sign and to investigate its pathogenesis and methods for distinguishing from cervical lymph nodes to improve US diagnostic accuracy.

Methods: Retrospectively, patients were categorized into three groups: Group 1, with 36 patients showing parathyroid lesions with dual concentric echo signs; Group 2, with 40 patients displaying classic hypoechoic parathyroid lesions; and Group 3, comprising 36 patients with identified lymph nodes, which were all examined from January 2018 to December 2019. The clinical data on demographics, clinical symptoms, serum levels, histopathologic findings, and US image characteristics were thoroughly reviewed.

Results: According to the clinical data, no significant differences in demographics or lesion sizes were observed in Group 1 and Group 2 ($p > 0.05$). No significant variances were noted in biochemical markers, including PTH, T-25OHD, and ALP. However, a notable difference was identified in adjusted serum calcium levels, which were significantly lower in Group 1 compared

Abbreviations: PHPT=primary hyperparathyroidism, US=ultrasound; PTH=parathyroid hormone, T-25OHD= total 25-hydroxy vitamin D; ALP= alkaline phosphatase, LNs= Lymph nodes.

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to Group 2 ($p < 0.05$). Additionally, the proportion of asymptomatic patients was significantly higher in Group 1 compared to Group 2 ($p < 0.05$). Pathological examination revealed that all lesions with dual concentric echo signs were parathyroid adenomas. The isoechoic central region predominantly corresponded to areas of loose edema, while the hypoechoic peripheral layer was primarily associated with chief and/or oncocytic cells. By comparing the ultrasonography of Groups 1 and 3, the parathyroid lesions with dual concentric echo signs exhibited significant distinctions from lymph nodes in size, blood flow classification, vascular distribution, and anatomical location ($p < 0.05$).

Conclusion: The parathyroid lesions with dual concentric echo signs in US corresponded to specific histopathological manifestations and relatively mild clinical features in the patients, this finding may increase the likelihood of incidental detection of parathyroid lesions by US. Attention to the details of size, location, and blood flow, especially, may aid US physicians in differentiating parathyroid adenomas from cervical lymph nodes.

Key points

I. Patients with PHPT with dual concentric echo signs tended to be asymptomatic and with normal or slightly elevated blood calcium levels. The identification of dual concentric echo signs may increase the likelihood of incidental identification of parathyroid lesions by US.
II. In the dual concentric echo sign, the isoechoic central region mainly corresponds to loose edema, and the hypoechoic peripheral layer mainly corresponds to chief/oncocytic cells. Its formation process may be associated with the pattern of blood supply.
III. Parathyroid lesions with dual concentric echo signs were similar to cervical lymph nodes on US, but had larger volumes, more abundant and predominantly mixed blood supply, and displayed a typical vascular arc sign. In contrast, lymph nodes are mainly located near the lower pole of the thyroid, with a primarily central portal blood supply and relatively less vascularity.

1. Introduction

Primary hyperparathyroidism (PHPT) is characterized by excessive production of parathyroid hormone (PTH), primarily due to clonal proliferation of neoplastic cells [1]. This condition disrupts calcium and phosphorus metabolism, leading to elevated blood calcium levels and a spectrum of clinical manifestations. PHPT can be clinically manifested by complications such as kidney stones and osteoporotic fractures, or asymptomatic, and incidentally discovered during unrelated medical evaluations. Asymptomatic individuals may still exhibit significant end-organ effects, including decreased cortical bone mineral density, hypercalciuria, nephrocalcinosis, and diminished creatinine clearance [2].

PHPT diagnostic approaches include high-resolution neck ultrasound (US), technetium-99m sestamibi (Tc-99m MIBI) subtraction scintigraphy, and contrast-enhanced four-dimensional computed tomography. US is the most economical, convenient, and safe method, and is widely used for parathyroid screening and localization in patients suspected of having PHPT. Typical US features for parathyroid adenomas are oval or lobulated extrathyroidal hypoechoic lesions with well-defined margins. Nonetheless, approximately 10 % of cases display atypical characteristics, including cystic parathyroid adenomas, cystic degeneration within solid adenomas, giant adenomas, and inhomogeneous, multilobulated, or calcified parathyroid tumors [3]. US sensitivity in diagnosing PHPT is reported as 76.1 %, with a positive predictive value of 93.2 % [4,5]. However, US diagnostic efficiency depends on the operator's skill and experience. Furthermore, US efficacy is compromised by the variability in the anatomical positioning of parathyroid nodules and diverse US appearances of these nodules. These factors require careful differentiation from other cervical structures, such as lymph nodes (LNs) and thyroid nodules. Consequently, there is a pressing need to enhance the diagnostic capabilities of US in this context.

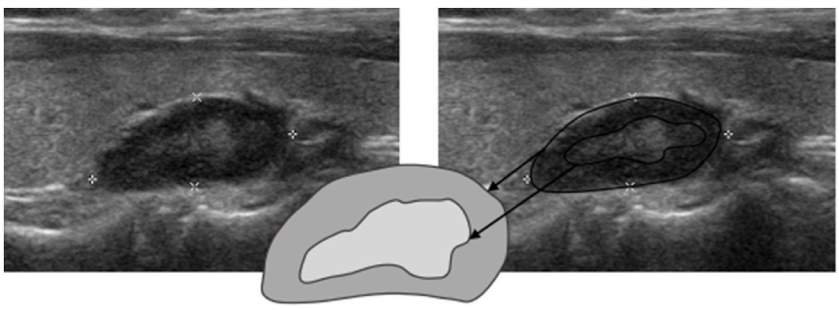

Fig. 1. The ultrasonography and diagram of dual concentric echo sign of parathyroid lesion in PHPT patient, which is present with two distinct echogenic layers-peripheral hypoechoic layer and isoechoic central zone.

A notable finding by Acar et al. [6] revealed that approximately 18 % of parathyroid adenomas exhibit a distinctive dual concentric echo sign on US, characterized by two distinct echogenic layers: a peripheral hypoechoic layer and an isoechoic central zone, as illustrated in Fig. 1. Our clinical observations have corroborated this finding, and noting that parathyroid nodules with that feature make it more difficult to distinguish from LNs on US than others. This study aims to re-examine the clinical and histopathological characteristics of parathyroid lesions displaying the dual concentric echo signs, elucidate the pathogenesis of this US feature, and further compare them with US features of cervical LNs to enhance diagnostic accuracy.

2. Methods

2.1. Patients selection

This retrospective study was divided into three distinct subgroups.

Group 1 Parathyroid lesions with dual concentric echo signs

Thirty-six patients who underwent preoperative US examinations from January 2018 to December 2019 were postoperatively diagnosed with PHPT at our institution and included in this subgroup. The inclusion criteria specified were as follows: individuals aged over 18 years, the presence of a single parathyroid lesion exhibiting a dual concentric echo sign on US, and the availability of biochemical and histopathological data. The exclusion criteria eliminated individuals with secondary or tertiary hyperparathyroidism, multiple gland disease, multiple endocrine neoplasia types 1 and 2A (MEN1, MEN2A), or hyperparathyroidism-jaw tumor syndrome.

Group 2 Parathyroid lesions with classic hypoechoic presentation

This subgroup comprised 40 patients who underwent preoperative US examinations between January 2018 and March 2018 and received a postoperative diagnosis of PHPT at our institution. The inclusion criteria for this group were identical to those of Group 1, with the exception that the single parathyroid lesion identified on US exhibits classic hypoechoic appearance. The criteria for exclusion were consistent with those applied to Group 1.

Group 3 Lymph Nodes

The third subgroup consisted of 36 patients who underwent neck US examinations between January 2018 and December 2018 and identified the presence of cervical LNs in the central compartment (sector VI). The inclusion criteria for this group were over 18 years old, with complete and useable US image data, with at least two follow-up visits documented no significant change in size, and no history of PHPT. Exclusion criteria for this group were the presence of lymphoma, metastatic LNs, and tuberculous lymphadenitis.

2.2. Procedure and data collection

The study protocol was approved by the hospital ethics committee and adhered to the Declaration of Helsinki. The US images and reports of all cases were searched and analyzed retrospectively through the US workstation (Philips Ultrasound, Bothell, WA, USA) of our hospital. Philips IU-22 and EPIQ-7 HDI linear probes (frequency, 5–12 MHz) were used for US examination, and two senior resident doctors identified and recorded the size, position, shape, internal echo, and blood supply characteristics of the lesions separately and discussed them with ultrasonographic specialists with over 5 years of experience when there was a disagreement.

The sex, age, clinical symptoms, highest preoperative serum PTH level, highest preoperative adjusted serum calcium level, lowest

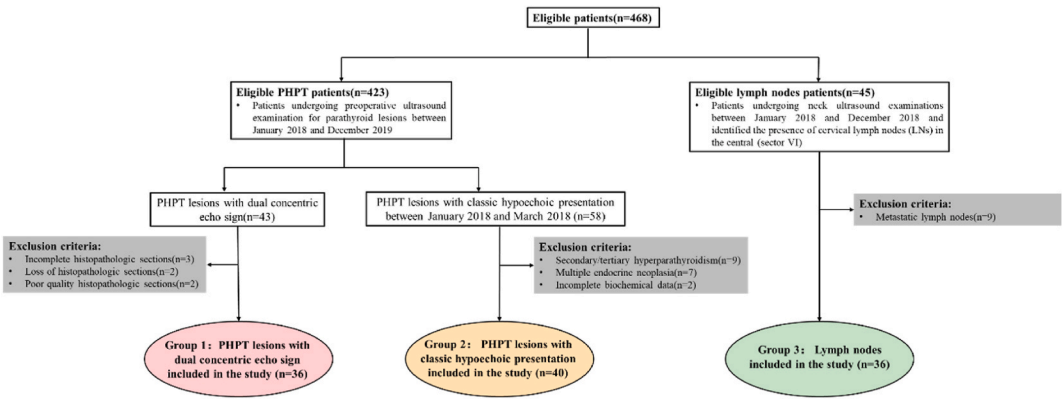

Fig. 2. Flow diagram of the study. The chart shows patients' inclusion and exclusion in the study.

preoperative serum total 25-hydroxy vitamin D (T-25OHD), alkaline phosphatase (ALP), surgical findings of the study patients were retrieved and reviewed with the clinical record system of our hospital. Histopathologic reports (pathologic diagnosis), and pathological sections, were reviewed by specialists from the histopathologic department of our hospital. Histopathologic results of parathyroid lesions were classified as parathyroid adenoma, atypical parathyroid tumor, and parathyroid carcinoma, due to the latest WHO classification of parathyroid tumors [1]. The study flow diagram is shown in Fig. 2.

Adler grade classifications were conducted based on the detected blood flow [7,8]. We divided the blood flow signal of the lesion into four classes. Adler 0 indicates no obvious blood flow signal; Adler I represents minimal flow, which refers to 1 or 2 small vessels with a diameter <1 mm; Adler II represents moderate flow, which means that one major vessel can be visualized, or 3–4 small vessels detected; Adler III represents marked flow, which refers to more than four vessels detected, or vessels intertwined into a network. Vessel distribution was further divided into four categories, absent, peripheral, central, and mixed (both peripheral and central). Parathyroid adenomas typically present with a prominent feeding artery, often entering the tumor from one pole along its long axis and forming an "arc" along its surface. Herein, we define it as a "vascular arc sign [9]". As shown in Fig. 3 (A-C).

2.3. Statistical analysis

Statistical analysis used IBM SPSS 25.0 software. Frequencies were used for categorical variables, with inter-group comparisons by Chi-Square/Fisher's tests. The Kolmogorov-Smirnov test determined distribution. Normally distributed data were described as means ± standard deviation, with t-tests for independent group comparisons. Non-normal data were presented as median and quartile, with Mann-Whitney U-tests for group comparisons. $P \leq 0.05$ was significant.

3. Results

3.1. Patient characteristics

This study analyzed 36 parathyroid lesions exhibiting dual concentric echo signs, comprising 72.2 % females with a mean age of 52.7 ± 14.4 years. Additionally, 40 parathyroid lesions with the classic hypoechoic presentation were examined, comprising 75.6 % females with a mean age of 53.5 ± 8.3 years. The maximum diameters of the lesions were found to be 19.4 ± 0.64 and 20.2 ± 0.77 mm, respectively.

The median PTH levels, with first and third quartiles (Q1, Q3), were recorded as 157.1 (120.5, 251.9) pg/mL for lesions with dual concentric echo signs and 165.0 (113.3, 277.0) pg/mL for those with classic hypoechoic presentation, against a reference range of 12–68 pg/mL. Adjusted calcium levels were observed at a median of 2.64 (2.50, 2.82) mmol/L for the former group and 2.82 (2.69, 2.94) mmol/L for the latter, a reference range of 2.13–2.62 mmol/L. The T-25OHD levels were 13.3 (8.95, 19.3) ng/mL and 14.8 (11.8, 19.7) ng/mL (reference range >30 ng/mL). ALP levels were at a median of 99.0 (82.5, 143.5) U/L for the first group and 100.5 (64.3, 144.3) U/L for the second, within the reference ranges of 50–130 U/L for females and 45–120 U/L for males.

All enrolled patients demonstrated positive results in Tc-99m MIBI parathyroid scintigraphy. A statistically significant difference was observed in the adjusted calcium levels between the two groups ($P = 0.017$). However, no statistically significant differences were found in the other characteristics measured ($P > 0.05$), as detailed in Table 1.

In the cohort of patients exhibiting dual concentric echo signs diagnosed with PHPT, a significant majority, 69.4 % (25/36), were asymptomatic at diagnosis. Within this subgroup, elevated calcium levels were observed in 22.2 % (8/36) of the patients, and 47.2 % (17/36) had incidentally discovered lesions. In contrast, only 22.5 % (9/40) of the patients with classic hypoechoic presentation were asymptomatic at diagnosis. The difference in the proportion of asymptomatic patients between the two groups was statistically significant ($P < 0.05$). The chief complaints among symptomatic patients encompassed a range of symptoms including nephrolithiasis, bone pain, fatigue, and a combination of polydipsia and polyuria (Table 2).

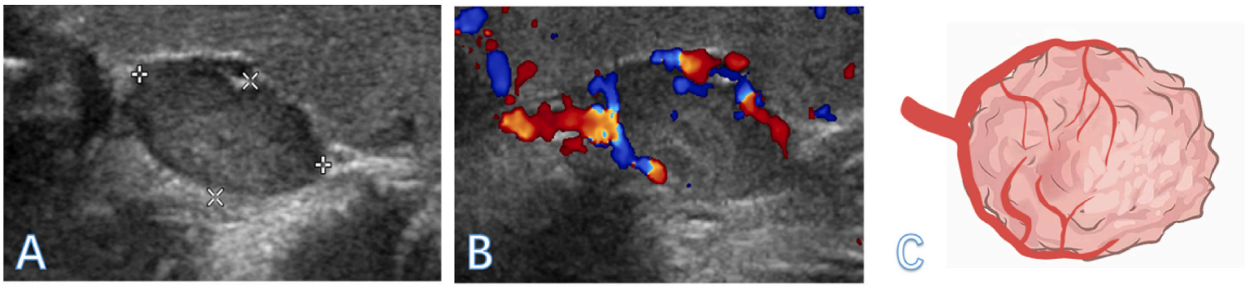

Fig. 3. Schematic representation of vascular arc sign and dual concentric echo sign in PHPT. (A, B)The ultrasound vascular arc sign characteristic of PHPT, where a prominent blood-supplying artery is observed entering the tumor along its longitudinal axis from one pole and then forming an arc along the tumor surface before branching into the tumor. (C) Schematic simulation of the vascular arc sign and dual concentric echo sign.

Table 1
Clinical characteristics of patients with PHPT.

Items	Parathyroid lesions with dual concentric echo signs (n = 36)	Parathyroid lesions with classic hypoechoic presentation (n = 40)	*P*-value
[a]Age, y	52.7 ± 14.4	53.5 ± 8.3	0.764
[a]Maximum diameter, mm	19.4 ± 0.64	20.2 ± 0.77	0.621
[b]PTH, pg/ml	157.1 (120.5251.9)	165.0 (113.3277.0)	0.971
[b]Adjusted calcium, mmol/L	2.64 (2.50,2.82)	2.82 (2.69,2.94)	**0.017**
[b]T-25OHD, ng/ml	13.3 (9.0,19.3)	14.8 (11.8,19.7)	0.249
[b]ALP, U/L	99.0 (82.5143.5)	100.5 (64.3144.3)	0.353
Positive Tc-99m MIBI parathyroid scintigraphy	36 (100)	40 (100)	–

Note. — Unless otherwise indicated, data are the number of patients, with percentages in parentheses. The boldface type indicates a significant difference. PTH = parathyroid hormone. T-25OHD = total 25-hydroxy vitamin D. ALP = alkaline phosphatase. Tc-99 m MIBI= Technetium-99 m sestamibi.

[a] Data are means ± standard deviation.

[b] Data are median, with lower and upper quartiles in parentheses.

Table 2
Chief complaints of study patients.

Chief complain	Parathyroid lesions with dual concentric echo signs (n = 36)	Parathyroid lesions with classic hypoechoic presentation (n = 40)	*P*-value
Asymptomatic	25 (69.4)	9 (22.5)	**0.000**
Increased serum calcium	8 (22.2)	6 (15.0)	
Parathyroid lesion found	17 (47.2)	3 (7.5)	
Symptomatic	11 (30.6)	31 (77.5)	
Urolithiasis	5 (13.9)	8 (20.0)	
Bone pain/bone fracture	5 (13.9)	16 (40.0)	
Fatigue	3 (8.3)	7 (17.5)	
Polydipsia/polyuria	2 (5.6)	2 (5.0)	

Note. —Data are the number of patients, with percentages in parentheses. The boldface type indicates a significant difference.

3.2. Histopathologic features of parathyroid lesions with dual concentric echo signs

Pathological diagnosis for parathyroid nodules with dual concentric echo signs was all parathyroid adenoma (36/36,100 %). Table 3 shows the main histopathological components. Parathyroid nodules with dual concentric echo signs often exhibited different peripheral and central components. The isoechoic central zone was mainly loose edema (80.1 %, 29/36). However, the peripheral layer, which was hypoechoic in the US, contained different types of cells, such as the chief cells with oncocytic cells (47.2 %,17/36) or oncocytic cell nodules (3/36,8.3 %). The rest of the nodules showed heterogeneous components such as acinar structures (25 %,9/36) or loose edema/fibers/vessels/capsule (19.4 %, 7/36), and exhibited relatively atypical dual concentric echo signs in the US (7/36,19.4 %). Typical cases and their histopathologic results are shown in Fig. 4 (A-D).

3.3. Differentiation of parathyroid lesions with dual concentric echo signs from LNs

Herein, the maximum diameter of parathyroid nodules with dual concentric echo signs ranged from 10 to 37 mm, with a mean diameter of 19.4 ± 0.64 mm. In contrast, LNs exhibited a maximum diameter range of 6–15 mm, with a mean diameter of 9.8 ± 0.23 mm. A statistically significant difference in the maximum diameters was observed between the two groups ($P < 0.05$). Regarding blood flow grading, parathyroid lesions predominantly exhibited grade II and III blood flow, whereas LNs were primarily characterized by grade 0 and I blood flow. Regarding vascular distribution, 86.1 % (31/36) of the parathyroid lesions displayed a mixed vascular pattern, while 61.1 % (22/36) of the LNs demonstrated a central vascular pattern. The typical "vascular arc sign" was observed in 83.3

Table 3
Pathological components of parathyroid nodules with dual concentric echo sign.

Pathological components	N (%)
Chief cell (with oncocytic cell) in the peripheral region and loose edema in the center	17 (47.2)
Oncocytic cell nodules with loose edema in the center	3 (8.3)
Mainly acinar structure with slight loose edema	9 (25)
Others: inhomogeneous distribution of loose edema and fiber; vessel; and capsules. etc	7 (19.4)

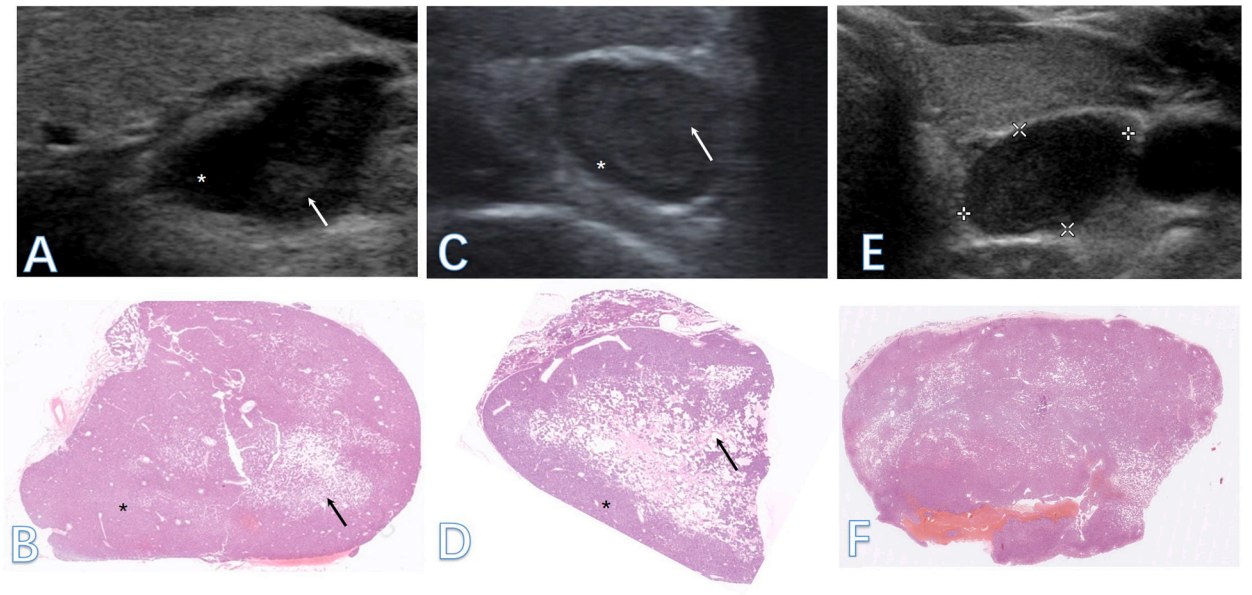

Fig. 4. Ultrasound and Microscopic Imaging of Parathyroid Lesions. (A, C) Ultrasound images of the neck displaying the dual concentric echo sign, characterized by a peripheral hypoechoic layer (*) and a central isoechoic area (arrow). (B, D) Corresponding low-magnification microscopy images (hematoxylin-eosin staining) showing predominantly tumor cells in the peripheral layer (*) and loose edema in the central area (arrow). (E) Ultrasound image depicting a classic hypoechoic PHPT lesion. (F) Corresponding low-magnification microscopic image illustrating diffusely distributed tumor cells.

% (30/36) of the patients with parathyroid lesions, which was not present in any of the LNs. The location distribution of parathyroid nodules was evenly split, with 25 % (9/36) in each position (upper left/right and lower left/right). Conversely, all LNs were in the lower pole of the thyroid gland. These location and vascular characteristics differences between parathyroid nodules and LNs were statistically significant ($P < 0.05$). For further details, refer to Table 4 and Fig. 5(A-D).

4. Discussion

In this retrospective study, we elucidated the clinical and histopathologic features of parathyroid lesions with a typical dual concentric echo sign on US. These findings contribute to the early identification and diagnosis of parathyroid lesions. Furthermore, we conducted a comparative analysis with cervical LNs, thereby facilitating differential diagnosis which may contribute to enhance the diagnostic accuracy of the US in PHPT.

Our findings indicate that parathyroid lesions presenting with dual concentric echo signs on US are more likely to be associated

Table 4
Characteristics of involved parathyroid nodules and lymph nodes.

Characteristic	Parathyroid lesions (n = 36)	lymph nodes (n = 36)	*P*-value
[1]Maximum diameter, mm	19.4 ± 0.64	9.8 ± 0.23	**0.000**
Blood flow signal Adler grade classifications			**0.000**
0	1 (2.8)	14 (38.9)	
I	3 (8.3)	16 (44.4)	
II	11 (30.6)	5 (13.9)	
III	21 (58.3)	1 (2.8)	
Vascular distribution			**0.000**
Absent	1 (2.8)	14 (38.9)	
Peripheral	4 (11.1)	0 (0)	
Central	0 (0)	22 (61.1)	
Mixed	31 (86.1)	0 (0)	
Vascular arc sign	30 (83.3)	0 (0)	**0.000**
Location			**0.000**
Upper left	9 (25)	0 (0)	
Upper right	9 (25)	0 (0)	
Lower Left	9 (25)	14 (38.9)	
Lower right	9 (25)	22 (61.1)	

Note. — Unless otherwise indicated, data are the number of patients, with percentages in parentheses. The boldface type indicates a significant difference. [1]Data are means ± standard deviation.

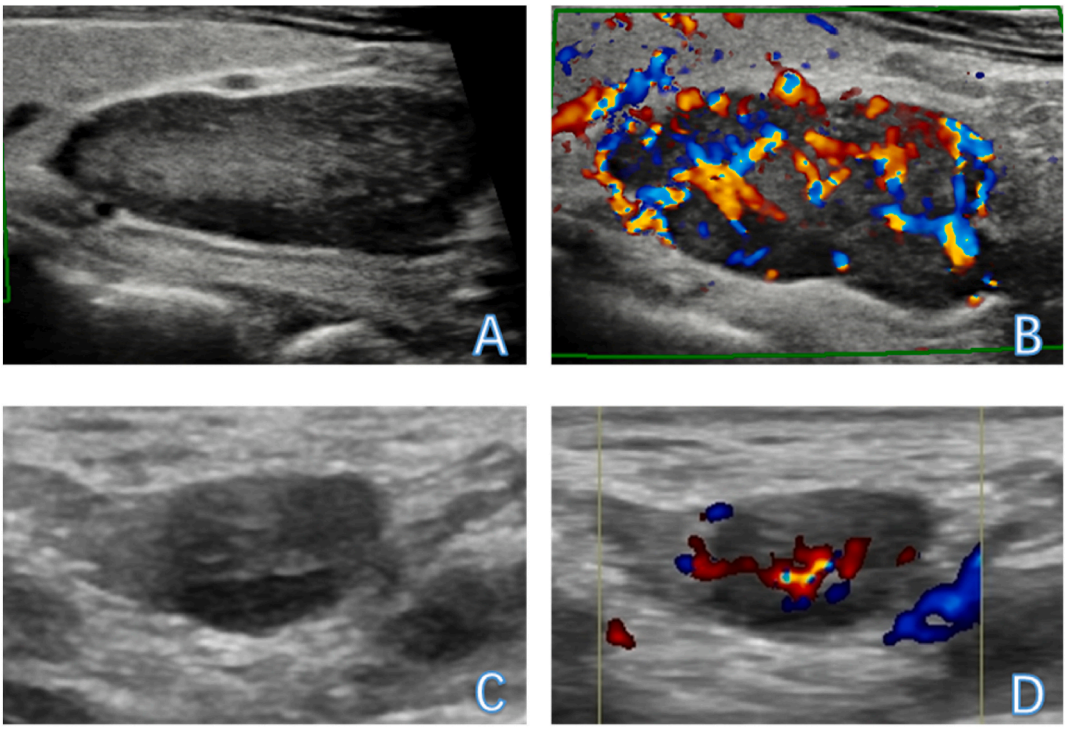

Fig. 5. Differentiation of parathyroid lesions from lymph nodes. A and B are two-dimensional and color Doppler images of a case of parathyroid adenoma, with vessels surrounding the periphery of the lesion and branches visible into the lesion. The blood flow intertwined in a mesh and irregularly arranged, classified as Adler grade III. C and D are two-dimensional and color Doppler images of a case of reactive hyperplastic lymph nodes, with a radially distributed blood flow signal centered on the lymphatic portal, classified as Adler grade II. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

with asymptomatic PHPT (aPHPT) and mildly elevated adjusted calcium levels than classic hypoechoic parathyroid lesions. aPHPT refers to patients who exhibit PTH levels or elevated blood calcium but lack typical clinical manifestations [10]. Epidemiological studies have shown that aPHPT has replaced classic symptomatic PHPT as the primary clinical type [11,12]. This increasing trend is primarily driven by the widespread adoption of blood calcium screening, which facilitates the identification of more patients with aPHPT from those with elevated calcium levels. In addition, the inadvertent detection of parathyroid nodules during neck US examinations plays an important role [13]. Herein, most (69.4 %,25/36) patients with dual concentric echo signs were asymptomatic at diagnosis. Among them, eight were evaluated due to elevated blood calcium levels, while the remaining 17 had their lesions incidentally detected during routine neck US examinations. Moreover, our observations suggest that parathyroid lesions with dual concentric echo signs did not tend to cause significant or severe hypercalcemia manifestations in patients. The median preoperative adjusted calcium level (Q1, Q3) of our patients was 2.64 (2.50, 2.82) mmol/L, which is only mildly elevated according to most laboratory criteria [14,15]. However, even if it does not cause severe hypercalcemia, it remains alert when US reveals a parathyroid lesion with dual concentric echo signs. As these patients are as likely to develop future clinical symptoms as hypercalcemia patients, most of whom exhibit end-organ damage within 5 years of diagnosis [16,17]. Despite the ongoing international debate regarding the necessity of surgery in patients with aPHPT, early intervention with timely conservative therapy may improve the patient's quality of life [18,19]. Therefore, early diagnosis is essential to preventing PHPT complications. In the context of the growing interest in opportunistic parathyroid adenoma evaluation, our findings have significant implications as a strategy to bridge the diagnostic gap in PHPT [20–22]. The presence of the dual concentric echo signs may increase confidence that a central compartment soft tissue nodule detected on US performed for a reason other than known PHPT represents a parathyroid adenoma and warrants further evaluation with biochemical testing. By accurately identifying parathyroid lesions with atypical presentations, our results may increase the likelihood of US incidental detection of PHPT, ultimately contributing to improved diagnostic accuracy and patient prognosis.

The final pathological diagnosis of lesions with dual concentric echo signs in our study was all parathyroid adenomas. The distribution of the pathological components differed in two layers: the central isoechoic region mainly corresponded to loose edema and peripheral hypoechoic layer mainly corresponded to chief cells/oncocytic cells, consistent with the previous study [23]. This finding indicates that compared with classical hypoechoic parathyroid lesions in the same volume, functional cell components were relatively less in lesions with dual concentric echo signs. As shown in Fig. 4(A-F).This may explain why these patients had relatively mild clinical symptoms and blood calcium levels elevated very slightly. This formation may be closely related to the characterization of its blood supply. The blood supply of parathyroid adenomas is typical of the vascular arc, and the central part of the lesion is far away from the vascular arc. Thus, the blood supply is relatively insufficient and gradually becomes a non-functional component, such as loose edema

tissue, which is isoechoic in the US. However, the periphery near the vascular arc has a relatively sufficient blood supply to facilitate the growth of the chief/oncocytic cells, which are hypoechoic in US. As shown in Fig. 3(A-C).

Precisely due to the dual concentric echo sign of these parathyroid lesions, it can be easily confused to differentiate with cervical LNs, as the corticomedullary structure of LNs almost manifests the same under US. To address this challenge, our study further involved 36 LNs located in the central compartment (sector VI) (including both normal and reactive hyperplastic LNs) in our study for comparative analysis. Firstly, our findings revealed that PHPT lesions were larger and exhibited richer blood supplies with predominantly grades II and III, compared to LNs. Second, the vascular distribution in parathyroid lesions was observed both peripherally and centrally, manifesting as the typical vascular arc sign instead of a radial pattern centered on the lymphatic hilum of the LNs (As shown in Fig. 5(A-D)). Third, LNs are mainly located around the lower pole of the thyroid gland, whereas parathyroid lesions are equally likely to occur around the upper and lower poles of the thyroid gland. These distinct characteristics in size, location, vascularity, and vascular distribution patterns aid in the differentiation of parathyroid lesions from cervical LNs during clinical US examination.

However, due to limited sample size and technical limitations, this study did not involve quantitative correlation analysis between the proportion of different echogenic regions of the dual concentric echo sign versus serum biochemicals. In addition, Acar et al. [6] previously reported that 80 % of the parathyroid adenomas with the dual concentric echo sign were adjacent to the lower poles of the thyroid gland, and the second mostly encountered location was the left superior location, which differed from our results, therefore expanding the sample size might be required for future study.

5. Conclusion

Parathyroid lesions with a dual concentric echo sign corresponded to a specific histopathological manifestation. Its formation process may be related to the blood supply. Patients with this kind of parathyroid lesions tended to be asymptomatic and with normal or slightly elevated blood calcium levels. Color Doppler may aid US physicians in differentiating parathyroid adenomas with dual concentric echo signs from cervical LNs. The above findings may contribute to the early identification for PHPT and increase the likelihood of incidental detection of parathyroid lesions by US.

Ethics statement

This study was reviewed and approved by the Institutional Review Board of Perking Union Medical College Hospital with the approval number: I-22PJ066, dated 2022-07-13.

Data availability

The data generated for this research has not yet been deposited in a publicly accessible repository. The original data were produced in the Department of Ultrasound, Peking Union Medical College Hospital, Chinese Academy of Medical Sciences and Peking Union Medical College, Beijing, China. Access to this data is subject to a stringent approval process to ensure compliance with ethical standards and patient confidentiality. Therefore, readers in need can contact the corresponding author Ke Lv, via email at lvke@163.com.

Author Contributions

Hua Liang and Jinglin Li, contributed equally to this article and are considered co-first authors, they both compiled and analyzed the data and wrote the first draft of the manuscript. Xin Yang: Data collection and pathological analysis. Yunshu Ouyang: Data collection. Ya Hu: Surgical data collection. Mei Li: Clinical data collection. Mengsu Xiao: Data collection. Yang Gui: Data collection. Xueqi Chen: Data collection. Li Tan: Data collection. Jianchu Li: Supervision. He Liu: Data collection. Ke Lv: Funding acquisition, Supervision, Writing - review & editing. Xiaoyan Chang: Supervision, pathological analysis. Yuxin Jiang: Supervision. Ke Lv and Xiaoyan Chang are co-correspondents.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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