Open Access

ISSN: 2663-9491 e-ISSN: 2789-6897

ORIGINAL ARTICLE

Correlation between Ultrasonographic Vascular Patterns and Cytological Diagnosis in Thyroid Nodules – A Prospective Study

DOI: 10.5281/zenodo.18116323

Noor Mohammed[1], Shafiqul Ahsan[1], Mahfuza Mahmud[1], Jamal[2], Elora Afroz Leema[1], Jalal Uddin[3], Asaduzzaman[4]

Received: 18 Dec 2025
Accepted: 24 Dec 2025
Published: 01 Jan 2026

Published by:
Gopalganj Medical College, Gopalganj, Bangladesh

Correspondence to
Noor Mohammed

ORCID
https://orcid.org/0009-0005-3707-0592

ABSTRACT

Background: *Thyroid nodules are frequent clinical findings, and distinguishing benign from malignant lesions remains a diagnostic challenge. Power Doppler Ultrasonography (PDUS) and Duplex Doppler Ultrasonography (DDUS) provide hemodynamic insights that may enhance differentiation. This study evaluated the correlation between Doppler vascular flow patterns and cytological outcomes in thyroid nodules.* ***Methods & Materials:*** *This cross-sectional study included 60 thyroid nodules from 43 patients assessed in the Radiology & Imaging Department of Mymensingh Medical College Hospital from October 2015 to October 2016. Patients with clinically suspected thyroid swelling were referred from ENT outpatient and indoor units. All underwent gray-scale B-mode ultrasonography, PDUS, DDUS with measurement of resistivity and pulsatility indices, and fine-needle aspiration cytology (FNAC) for confirmation. Vascularity was categorized into five patterns: Pattern I (absent flow), Pattern II (perinodular flow), Pattern III (perinodular plus central flow), Pattern IV (central > perinodular flow), and Pattern V (purely central flow). Statistical correlations between Doppler findings and FNAC were analyzed using Fisher's exact test.* ***Results:*** *The mean patient age was 39.3 ± 14.3 years, with a female predominance. Patterns I–III were found mainly in benign nodules (75.0%, 95.0%, and 88.9%), whereas Patterns IV and V strongly correlated with malignancy (83.3% and 100%; $p < 0.001$). DDUS classified 65.0% of nodules as benign and 35.0% as malignant based on Doppler indices, showing significant correlation with FNAC ($p < 0.001$). PDUS demonstrated high diagnostic performance, with 93.8% sensitivity, 88.6% specificity, and 90.0% accuracy.* ***Conclusion:*** *Central or predominantly central vascularity (Patterns IV and V) strongly predicts malignancy. Combined PDUS and DDUS serve as valuable non-invasive adjuncts to FNAC, improving diagnostic confidence and guiding biopsy decisions.*

Keywords: *Thyroid Nodule; Power Doppler Ultrasonography; Duplex Doppler; Vascular Flow Pattern; Resistivity Index; Pulsatility Index; Fine-Needle Aspiration Cytology; Thyroid Malignancy*

(The Insight 2025; 8(3): 673-678)

1. *Associate Professor, Department of Radiology & Imaging, Dhaka Medical College & Hospital, Dhaka, Bangladesh*
2. *Assistant Professor, Department of Radiology & Imaging, Dhaka Medical College & Hospital, Dhaka, Bangladesh*
3. *Assistant Professor, Department of Radiology & Imaging, National Institute of Burn & Plastic Surgery, Dhaka, Bangladesh*
4. *Assistant Professor, Department of Radiology & Imaging, National Gastroliver Institute & Hospital, Dhaka, Bangladesh*

INTRODUCTION

Thyroid nodules are one of the most common endocrine disorders encountered in clinical practice, with a prevalence ranging from 4–7% by palpation and up to 50–70% when detected incidentally by ultrasonography.[1,2] Although most thyroid nodules are benign, approximately 5–15% may harbor malignancy, necessitating careful evaluation to ensure timely diagnosis and management.[3] The key clinical challenge lies in accurately distinguishing benign from malignant nodules using reliable, non-invasive techniques.

Fine-needle aspiration cytology (FNAC) is widely accepted as the gold standard diagnostic tool for evaluating thyroid nodules. However, FNAC is invasive and may yield inconclusive or indeterminate results in 10–20% of cases, particularly in nodules with cystic or hemorrhagic components.[4,5] Consequently, there has been growing interest in ultrasonography (USG) as a first-line imaging modality due to its ability to characterize nodular morphology and vascularity with high spatial resolution.[6] Conventional B-mode ultrasonography provides valuable morphological features—such as echogenicity, margin definition, calcification pattern, and the presence or absence of a halo—that may suggest malignancy.[7,8] However, overlap between benign and malignant appearances often limits diagnostic accuracy. The incorporation of Doppler ultrasonography, including Power Doppler (PDUS) and Duplex Doppler (DDUS) techniques, offers additional insight by assessing intranodular and perinodular blood flow as well as quantitative hemodynamic parameters such as resistivity index (RI) and pulsatility index (PI).[9] Previous studies have demonstrated that malignant nodules tend to show increased central vascularity and elevated RI and PI values, reflecting neoangiogenesis and abnormal tumor vascular architecture.[10,11] Conversely, benign nodules generally exhibit absent or peripheral flow

patterns due to compression of normal thyroid tissue and encapsulation.[12] These Doppler flow characteristics may therefore serve as useful non-invasive indicators of malignancy, complementing the morphological data obtained from gray-scale imaging. Despite several studies highlighting the diagnostic potential of Doppler parameters, results remain variable across populations and imaging protocols.[13,14] Furthermore, limited data are available from South Asian populations, where the pattern of thyroid disease and access to diagnostic resources may differ. The present prospective study was conducted to evaluate the correlation between ultrasonographic vascular flow patterns and cytological findings in thyroid nodules. By analyzing Power Doppler and Duplex Doppler parameters in relation to FNAC results, this study aimed to determine the diagnostic validity, sensitivity, and specificity of vascular flow assessment in differentiating benign from malignant thyroid nodules.

METHODS & MATERIALS

Study Design and Population

This cross-sectional study was carried out amoung 60 thyroid nodules of 43 patients in the department of Radiology & Imaging of Mymensingh Medical College Hospital, Mymensingh. For this purpose, the patients with clinically diagnosed thyroid swelling were referred to the above department from OPD (outpatient department) & indoor of ENT during October 2015 to October 2016. All participants presented with clinically or sonographically detected thyroid nodules and were referred for ultrasonographic evaluation and FNAC correlation.

Inclusion and Exclusion Criteria

Inclusion criteria:

- Patients aged 16 years and above with solitary or multiple thyroid nodules.
- Patients who consented to undergo both Doppler ultrasonography and FNAC.

Exclusion criteria:

- Patients with diffuse thyroid enlargement without discrete nodules.
- Those with a history of thyroid surgery, radiotherapy, or incomplete diagnostic data.
- Cystic nodules with >90% fluid content or with hemorrhage that precluded Doppler assessment.

Ultrasonographic Evaluation

All examinations were performed using a high-resolution ultrasound machine equipped with a 7–12 MHz linear transducer. Each nodule was evaluated in B-mode, Power Doppler (PDUS), and Duplex Doppler (DDUS) modes.

B-mode parameters included:

- Echogenicity (hypoechoic, isoechoic, hyperechoic)
- Composition (solid, cystic, mixed)
- Margin (well-defined or ill-defined)
- Halo presence
- Calcification type (micro or macro)

Power Doppler was used to assess vascularity and classify flow into five patterns:

- **Pattern I:** Absent blood flow
- **Pattern II:** Perinodular flow only
- **Pattern III:** Perinodular and central flow
- **Pattern IV:** Central > perinodular flow
- **Pattern V:** Exclusively central flow[1].

Duplex Doppler was performed for spectral analysis of nodular arteries, and Resistivity Index (RI) and Pulsatility Index (PI) were calculated automatically.

Cytological Evaluation

FNAC was performed on all nodules under ultrasound guidance using a 23-gauge needle, and samples were analyzed by experienced cytopathologists. Cytological findings were categorized as benign, suspicious for malignancy, or malignant according to the Bethesda classification system.[2]

Statistical Analysis

All data were entered into SPSS version 16.0 for analysis. Continuous variables were expressed as mean ± standard deviation. Associations between vascular patterns, Doppler indices, and cytological results were assessed using Fisher's exact test. A *p*-value of <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

The study included 43 patients with 60 thyroid nodules. The mean age was 39.3 ± 14.3 years (range: 16–72 years), with a female predominance. The most common presenting complaint was neck swelling, often accompanied by mild discomfort or dysphagia in a few patients. Multinodularity was observed in most cases, with 41.9% on the right lobe and 58.1% on the left lobe.

Table – I: Distribution of Study Patients by Age and Sex (*n* = 43)

Variables	Number	Percentage (%)
Age group (years)		
11–20	4	9.3
21–30	9	20.9
31–40	11	25.6
41–50	8	18.6
51–60	7	16.3
>60	4	9.3
Sex		
Male	13	30.2
Female	30	69.8

Gray-Scale (B-mode) Ultrasonographic Features

On B-mode evaluation, benign nodules were generally isoechoic or cystic, with well-defined margins, peripheral haloes, and macrocalcifications. In contrast, malignant nodules were characteristically hypoechoic, solid, with ill-defined margins, absence of haloes, and microcalcifications. These features showed a significant association with cytological diagnosis ($p < 0.05$).

Table – II: Distribution of Nodules by Vascular Flow Pattern on PDUS and Cytological Outcome (*n* = 60)

Vascular Pattern	Description	No. of Nodules	Benign n (%)	Malignant n (%)
I	Absent blood flow	4	3 (75.0)	1 (25.0)
II	Perinodular flow only	20	19 (95.0)	1 (5.0)
III	Perinodular + central flow	18	16 (88.9)	2 (11.1)
IV	Central > perinodular flow	12	2 (16.7)	10 (83.3)
V	Exclusively central flow	6	0 (0.0)	6 (100.0)
Total	—	60	40 (66.7)	20 (33.3)

ISSN: 2663-9491 e-ISSN: 2789-6897

There was a highly significant correlation between vascular flow pattern and cytological diagnosis ($p < 0.001$, Fisher's exact test). Patterns IV and V were strongly associated with malignancy, while Patterns I–III were indicative of benignity.

Table – III: Correlation Between DDUS Findings and FNAC Results ($n = 60$)

DDUS (RI & PI Evaluation)	Benign n (%)	Suspicious n (%)	Malignant n (%)
Benign	39 (65.0)	—	—
Suspicious	—	2 (3.3)	—
Malignant	—	—	21 (35.0)
Total	39 (65.0)	2 (3.3)	21 (35.0)

The Doppler spectral analysis (using RI and PI) classified approximately two-thirds of the nodules as benign and one-third as malignant. This pattern demonstrated a statistically significant correlation with FNAC ($p < 0.001$).

Table – IV: Cytological Diagnosis of Thyroid Nodules by FNAC ($n = 60$)

Cytological Diagnosis	Number	Percentage (%)
Benign	44	73.3
Suspicious for malignancy	6	10.0
Malignant	10	16.7

FNAC confirmed the majority of nodules as benign (73.3%), while 26.7% were either suspicious or malignant.

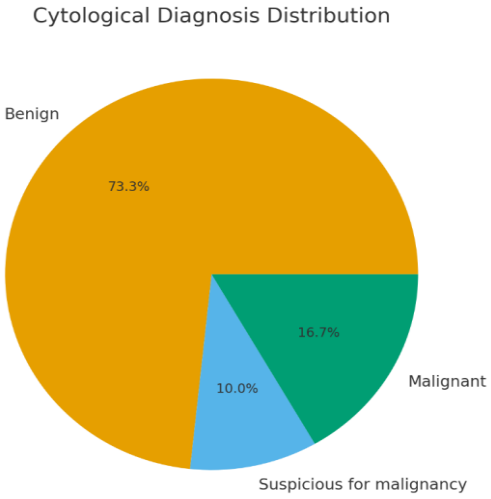

Figure – 1: Cytological Diagnosis of Thyroid Nodules by FNAC

Correlation Between Imaging and Cytology

Both PDUS and DDUS findings showed significant positive correlation with cytological outcomes ($p < 0.001$).

- Benign nodules consistently exhibited peripheral or absent flow with low RI/PI values,
- While malignant nodules showed predominant central vascularity with elevated RI and PI.

Table – V: Diagnostic Validity of Ultrasonographic Parameters in Detecting Malignancy

Parameter	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
PDUS	93.8	88.6	90.0	75.0	97.5
RI	81.3	81.8	81.7	61.9	92.3
PI	75.0	79.5	78.3	57.1	89.7

Among the 60 nodules, vascular flow analysis on PDUS revealed a clear trend — increasing central vascularity strongly correlated with malignant cytology. Patterns IV and V were highly predictive of malignancy (83.3% and 100% respectively), whereas Patterns I–III were largely benign. Spectral Doppler indices (RI and PI) were also significantly higher in malignant nodules ($p < 0.001$). The diagnostic performance of PDUS surpassed that of RI and PI alone, yielding excellent sensitivity (93.8%) and specificity (88.6%). Overall, combining gray-scale features, vascular patterns, and Doppler indices greatly enhanced diagnostic accuracy, allowing reliable differentiation between benign and malignant thyroid nodules prior to FNAC confirmation.

ISSN: 2663-9491 e-ISSN: 2789-6897

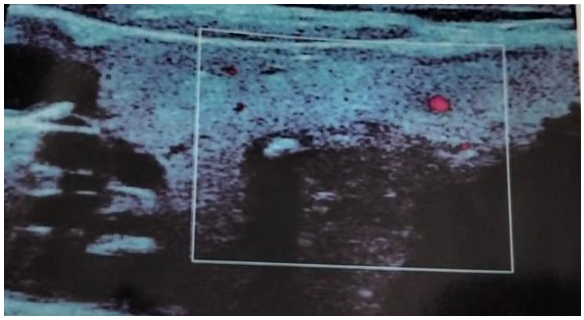

Figure – 2: Absence of signal blood flow (Vascular flow pattern I)

Here the nodule is hypoechoic having macrocalcification with posterior shadowing & no haloes.

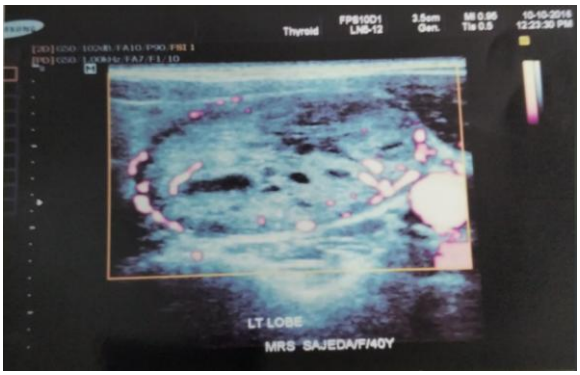

Figure – 3: Exclusively perinodular blood flow (Vascular flow pattern II)

Here the nodule is mixed echogenic (predominantly solid with cystic change) having haloes with no calcification.

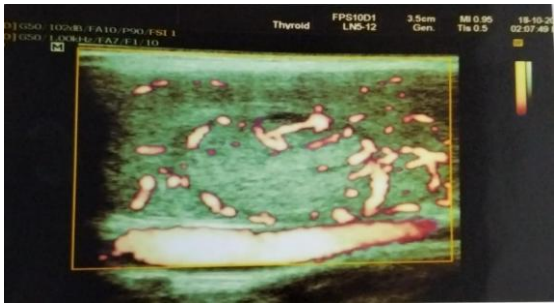

Figure – 4: Perinodular > central blood flow (Vascular flow pattern III)

Here the nodule is iso-echoic & solid having haloes with no calcification.

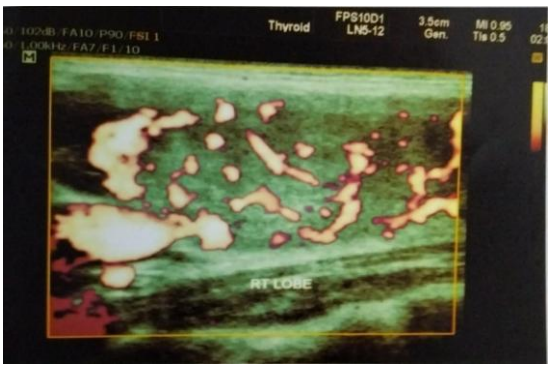

Figure – 5: Central > or = perinodular blood flow (Vascular flow pattern IV)

Here the nodule is iso-echoic, solid & ill defined outlined having no calcification & haloes.

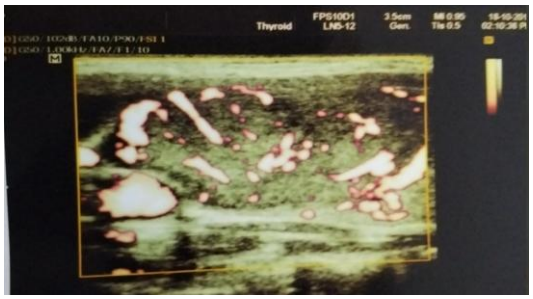

Figure – 6: Central > or = perinodular blood flow (Vascular flow pattern IV)

Here the nodule is iso-echoic, solid & ill defined outlined having no calcification & haloes.

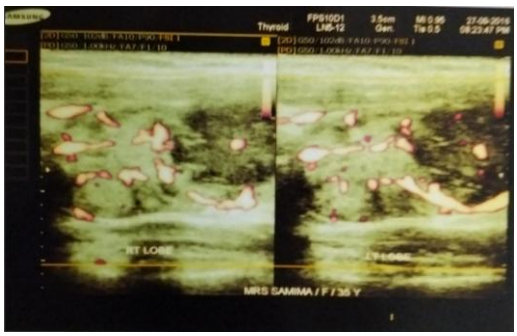

Figure – 7: Exclusively central blood flow (Vascular flow pattern V)

Here the nodule is solid & part of it is hypo-echoic with ill defined irregular outlined having no calcification & haloes.

DISCUSSION

Differentiation between benign and malignant thyroid nodules remains a major diagnostic challenge in endocrine imaging. Although fine-needle aspiration cytology (FNAC) is considered the gold standard, it is invasive and sometimes yields indeterminate results. Consequently, ultrasonography (USG) — particularly Power Doppler (PDUS) and Duplex Doppler (DDUS) — has gained prominence as a non-invasive adjunct that provides valuable morphological and hemodynamic information for risk stratification.[1,2]

In this prospective study of 43 patients with 60 thyroid nodules, we evaluated the correlation between vascular flow patterns on PDUS, Doppler indices (resistivity index and pulsatility index), and cytological findings. The results revealed a strong, statistically significant association between increasing central vascularity and malignancy, consistent with previously published literature.[3,4] Patterns IV and V, characterized by predominant or exclusive central blood flow, were highly predictive of malignant pathology, whereas peripheral or absent vascularity (Patterns I–III) was strongly suggestive of benign nodules. The mean age of patients (39.3 ± 14.3 years) and the female predominance in our series align with the demographic distribution reported in other regional and international studies.[5,6] Most patients presented with anterior neck swelling, and multinodularity was frequent, findings typical of benign thyroid disease but not exclusive to it. Our B-mode observations supported the established criteria for malignancy: hypoechogenicity, solid consistency, irregular or ill-defined margins, microcalcifications, and absence of a peripheral halo.[7,8] In contrast, isoechoic or cystic lesions with smooth margins and macrocalcifications were predominantly benign. These morphological clues, when integrated with vascular and spectral Doppler data, significantly improve pre-operative diagnostic confidence. The current study demonstrated that PDUS achieved a sensitivity of 93.8%, specificity of 88.6%, and diagnostic accuracy of 90.0%, values comparable to those of Liu et al.[9], who reported 92% sensitivity and 85% specificity. The addition of spectral Doppler parameters further refined diagnostic performance. Although the resistivity index (RI) and pulsatility index (PI) alone had lower predictive values (accuracy 81.7% and 78.3%, respectively), their combination with PDUS patterns substantially improved overall diagnostic efficacy. These results are in agreement with the findings of Rago et al.[10] and Lyshchik et al.[11], who emphasized that malignant nodules often display high RI and PI values reflecting increased vascular resistance secondary to neoangiogenesis and disorganized vascular architecture. A critical observation in our study was that central vascularity was consistently associated with malignant nodules, possibly due to angiogenic activity within the tumor core. Benign nodules typically derive blood supply from surrounding thyroid tissue, hence showing a peripheral flow pattern[12]. However, certain benign hyperplastic nodules may show central flow, underscoring the importance of correlating Doppler features with gray-scale morphology and cytology before making management decisions. The strong positive correlation between PDUS, DDUS, and FNAC results ($p < 0.001$) highlights the potential role of Doppler ultrasonography as an effective screening and triaging tool for thyroid nodules. By identifying high-risk vascular patterns, clinicians can prioritize nodules for FNAC, thus reducing unnecessary biopsies in clearly benign-appearing lesions. Several studies have also supported this integrated approach. Moon et al.[13] demonstrated that combining B-mode features with Doppler flow patterns achieved diagnostic accuracies approaching 90%. Similarly, Chammas et al.[14] found that vascular pattern assessment increased the sensitivity of ultrasound for detecting malignancy, particularly when central or chaotic flow was evident. In our study, the negative predictive value (97.5%) of PDUS was particularly high, indicating that nodules lacking central vascularity or displaying exclusively peripheral flow are highly likely to be benign. This finding supports the use of PDUS as a reliable exclusion test, enhancing patient reassurance and avoiding unnecessary interventions.[15,16] However, certain limitations should be acknowledged. The sample size was modest, and the number of malignant nodules was smaller compared to benign ones, which might affect the precision of sensitivity estimates. Moreover, vascular flow assessment is somewhat operator-dependent and may be influenced by machine settings, patient movement, or nodule depth. Future studies with larger sample sizes, quantitative vascular scoring, and integration with elastography or contrast-enhanced ultrasonography may further refine diagnostic algorithms. In our study study reaffirms that ultrasonographic vascular flow patterns are significantly correlated with cytological diagnosis. Patterns IV and V, reflecting central or predominant central flow, are highly suggestive of malignancy, while peripheral or absent flow strongly indicates benign pathology. Power Doppler and Duplex Doppler ultrasonography, when combined with B-mode imaging, constitute a sensitive, specific, and non-invasive approach that enhances diagnostic accuracy and optimizes the selection of nodules for FNAC.

CONCLUSION

The present study demonstrates a significant correlation between ultrasonographic vascular flow patterns and cytological diagnosis in thyroid nodules. Increasing central vascularity, represented by vascular patterns IV and V, was strongly predictive of malignancy, while absent or peripheral vascularity (patterns I–III) indicated benignity. Power Doppler ultrasonography showed excellent sensitivity and specificity, confirming its value as a non-invasive and reliable diagnostic adjunct to FNAC. Duplex Doppler indices, particularly elevated RI and PI values, further enhanced diagnostic confidence. Combining gray-scale features with Doppler parameters allows accurate preoperative differentiation of benign and malignant nodules, guiding clinicians in patient selection for FNAC or surgical management. Thus, Power and Duplex Doppler ultrasonography should be routinely integrated into thyroid imaging protocols to improve diagnostic efficiency and reduce unnecessary invasive procedures.

REFERENCES

1. *Brander A, Viikinkoski P, Nickels J, Kivisaari L. Thyroid gland: ultrasound screening in a random adult population. J Clin Ultrasound. 1991;19(6):375–381.*
2. *Guth S, Theune U, Aberle J, Galach A, Bamberger CM. Very high prevalence of thyroid nodules detected by high frequency (13 MHz) ultrasound examination. Eur J Clin Invest. 2009;39(8):699–706.*
3. *Hegedüs L. Clinical practice. The thyroid nodule. N Engl J Med. 2004;351(17):1764–1771.*
4. *Gharib H, Goellner JR. Fine-needle aspiration biopsy of the thyroid: an appraisal. Ann Intern Med. 1993;118(4):282–289.*
5. *Baloch ZW, LiVolsi VA, Asa SL, Rosai J, Merino MJ, Randolph G, et al. Diagnostic terminology and morphologic criteria for cytologic diagnosis of thyroid lesions: The Bethesda System for Reporting Thyroid Cytopathology. Diagn Cytopathol. 2008;36(6):425–437.*
6. *Frates MC, Benson CB, Doubilet PM, Kunreuther E, Contreras M, Cibas ES, et al. Prevalence and distribution of carcinoma in patients with solitary and multiple thyroid nodules. Radiology. 2005;237(3):794–800.*

7. *Moon WJ, Jung SL, Lee JH, Na DG, Baek JH, Lee YH, et al. Benign and malignant thyroid nodules: US differentiation—multicenter retrospective study. Radiology. 2008;247(3):762–770.*
8. *Kim EK, Park CS, Chung WY, Oh KK, Kim DI, Lee JT, et al. New sonographic criteria for recommending fine-needle aspiration biopsy of nonpalpable solid nodules of the thyroid. AJR Am J Roentgenol. 2002;178(3):687–691.*
9. *Chammas MC, Gerhard R, de Oliveira IR, Widman A, Santos A, Cerri GG. Thyroid nodules: evaluation with power Doppler and duplex Doppler ultrasonography. J Clin Ultrasound. 2005;33(3):94–98.*
10. *Lyshchik A, Drozd V, Demidchik Y, Reiners C. Diagnosis of thyroid cancer in children: value of gray-scale and power Doppler US. Radiology. 2005;237(1):202–211.*
11. *Rago T, Vitti P, Chiovato L, Mazzeo S, De Liperi A, Miccoli P, et al. Role of conventional ultrasonography and color flow-Doppler sonography in predicting malignancy in cold thyroid nodules. J Clin Endocrinol Metab. 1998;83(12):4520–4525.*
12. *Tamsel S, Demirpolat G, Erdogan M, Nart D, Karadeniz M, Uluer H, et al. Power Doppler US patterns of vascularity and spectral Doppler US parameters in benign and malignant thyroid nodules. Diagn Interv Radiol. 2007;13(3):122–128.*
13. *Moon HJ, Kwak JY, Kim MJ, Son EJ, Kim EK. Can vascularity at power Doppler US help predict thyroid malignancy? Korean J Radiol. 2011;12(1):1–14.*
14. *Chammas MC, De Oliveira IR, Barros N, Durazzo M, Cerri GG. Doppler ultrasound of the thyroid gland. Ultrasound Med Biol. 2013;39(12):2332–2340.*
15. *Lagalla R, Caruso G, Romano G, Midiri M. Doppler evaluation of thyroid diseases. Eur Radiol. 1998;8(1):146–150.*
16. *Liu Y, Wang L, Liu Z, Xu D. Diagnostic accuracy of power Doppler ultrasound in thyroid nodules. Clin Radiol. 2010;65(6):483–488.*