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Diagnostic Role of Morphologic and Vascular Sonographic Criteria in Characterizing Ovarian Tumours

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Abstract
Ovarian cancer remains a major cause of gynaecologic malignancy-related mortality worldwide. Early and accurate differentiation of benign from malignant ovarian masses is essential for appropriate surgical planning and referral. While gray-scale ultrasonography provides valuable morphological information, Colour and Spectral Doppler imaging can add physiologic insights by assessing tumour vascularity and impedance to blood flow. Aim of the study was to evaluate the diagnostic efficacy of combined morphologic and vascular sonographic (Colour and Spectral Doppler) criteria in differentiating benign and malignant ovarian tumours and to correlate these findings with histopathology. This prospective observational study was conducted in the Department of Radiology over a period of 12 months on 50 female patients presenting with ovarian or adnexal masses. All patients underwent gray-scale ultrasonography followed by Colour and Spectral Doppler assessment. Morphologic parameters (size, wall thickness, septations, papillary projections, echogenicity, ascites) and vascular parameters (pattern of flow, Resistive Index [RI], Pulsatility Index [PI]) were documented. The lowest RI and PI from the most prominent intratumoral vessel were recorded. A cut-off of RI < 0.4 and PI < 1.0 was used to indicate malignancy. Histopathological diagnosis following surgery or biopsy served as the gold standard. Statistical analysis was performed using SPSS version 25.0, with sensitivity, specificity, predictive values, and ROC curves calculated. Out of 50 cases, 32 (64%) were benign and 18 (36%) malignant on histopathology. Peripheral vascularity predominated in benign lesions (65.6%), while central/mixed flow was typical of malignant lesions (83.3%). The mean RI and PI values were 0.68 ± 0.07 and 1.35 ± 0.14 for benign, and 0.40 ± 0.06 and 0.82 ± 0.10 for malignant lesions, respectively ($p < 0.001$). Using morphology alone, ultrasound achieved 78.9% sensitivity, 90.3% specificity, and 86.0% accuracy. When Doppler criteria were added, diagnostic accuracy improved to 92.0% (sensitivity 88.9%, specificity 93.7%). ROC analysis demonstrated an AUC of 0.96 for combined morphologic and Doppler criteria. Combined morphologic and vascular sonographic assessment significantly enhances diagnostic accuracy in differentiating benign from malignant ovarian tumours. Incorporating Doppler indices (RI, PI) with structural features yields high sensitivity and specificity, supporting its integration into standardized evaluation systems such as IOTA Simple Rules and O-RADS US for improved preoperative triage.

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Key Words
Ovarian tumour, colour doppler, resistive index, pulsatility index, morphologic criteria, ultrasonography, adnexal mass differentiation

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INTRODUCTION

Transvaginal gray-scale ultrasonography remains the primary modality for initial characterization of adnexal masses, with morphologic features solid components, papillary projections, septations, wall irregularity, and ascites providing robust discrimination between benign and malignant disease[1]. Over the past two decades, standardized morphologic frameworks such as the International Ovarian Tumor Analysis (IOTA) "Simple Rules" and related models have shown high reproducibility and accuracy for preoperative triage[2]. Vascular assessment with Doppler adds physiologic information low resistive or pulsatility indices and chaotic neovascular patterns that may reflect tumor angiogenesis; however, meta-analyses and comparative studies report mixed incremental benefit over morphology alone, with some suggesting only modest or context-dependent gains[3]. Risk-stratification systems that combine sonography with clinical or laboratory data (e.g., the Risk of Malignancy Index incorporating CA-125 and menopausal status) remain widely used but may be outperformed by expert subjective assessment or structured morphologic models in specialist settings[4]. To harmonize reporting and management, the American College of Radiology introduced O-RADS US (2019-2020), integrating IOTA-based lexicon and risk categories, yet evidence that still highlighted variation in thresholds for Doppler indices (RI/PI), operator dependence, and limited prospective evaluations assessing the true incremental value of vascular criteria when added to modern morphologic rules[5]. Emerging techniques such as 3D/power Doppler and vessel-morphology analysis suggested potential improvements but lacked consistent validation across diverse populations before 2021 (6). Earlier few prospective, histology-verified studies directly quantified the incremental diagnostic yield of adding vascular Doppler criteria to standardized morphologic frameworks across generalist and specialist operators, and across benign mimics (e.g., borderline tumors, endometriomas). Aim of the study was to evaluate, in a consecutive cohort of adnexal masses with histopathologic reference, the diagnostic performance of combined morphologic and vascular Doppler criteria versus morphology alone, and to determine the incremental value of vascular indices within a standardized reporting framework suitable for routine practice.

MATERIAL AND METHODS

Study Design and Setting: This prospective observational study was carried out in the Department of Radiology, over a period of 12 months, after obtaining clearance from the Institutional Ethical Committee. The study aimed to evaluate the diagnostic role of combined morphologic and vascular sonographic criteria in differentiating benign and malignant ovarian tumours.

Sample Size and Selection Criteria: A total of 50 female patients aged between 18 and 70 years, who presented with adnexal or ovarian masses on clinical or initial ultrasound examination, were included in the study. Patients with a history of prior pelvic surgery, chemotherapy, or radiotherapy, as well as those with inadequate sonographic visualization due to obesity or bowel gas, were excluded. Written informed consent was obtained from all participants.

Equipment and Technique: All patients underwent gray-scale and Doppler ultrasonography using a high-resolution ultrasound machine equipped with transabdominal (3.5-5 MHz) and transvaginal (5-7.5 MHz) probes. The gray-scale study included assessment of lesion size, wall thickness, septations, papillary projections, solid or cystic areas, echogenicity, and presence of ascites. Morphologic characterization was performed according to IOTA Simple Rules and Descriptors where applicable.

Doppler Evaluation: Following the gray-scale scan, Colour and Spectral Doppler imaging was performed to assess vascularity. The pattern of blood flow was documented as peripheral, central, or mixed. Quantitative Resistive Index (RI) and Pulsatility Index (PI) were measured by placing the Doppler sample gate on the most prominent intratumoral vessel, ensuring proper angle correction. The lowest RI and PI values were recorded for each lesion. An RI < 0.4 and PI < 1.0 were considered suggestive of malignancy (Kurjak 1992; Kinkel 2000).

Histopathological Correlation: All patients subsequently underwent surgical excision or biopsy of the adnexal mass. The histopathological diagnosis served as the gold standard for differentiating benign and malignant lesions. Ultrasonographic findings were correlated with histopathology for final validation.

Data Analysis: All data were compiled and analyzed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± SD, and categorical variables as percentages. Diagnostic performance of morphological, vascular, and combined criteria was evaluated by calculating sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. Comparative diagnostic performance was assessed using Receiver Operating Characteristic (ROC) curve analysis, and a p-value < 0.05 was considered statistically significant.

RESULTS AND DISCUSSIONS

In this study, fifty female patients aged between 18 and 70 years (mean age 42.6 ± 12.3 years) were evaluated. All patients were female by study design. The majority were premenopausal (64%), while 36% were postmenopausal. The most common presenting symptom was abdominal pain (44%), followed by abdominal mass (30%) and menstrual irregularities (16%). Lesions were more frequently located in the right ovary (56%) than in the left (40%), with bilateral involvement in 4% of cases (Table 1).

Following the gray-scale evaluation, Colour and Spectral Doppler imaging was performed in all 50 cases to assess intratumoral and peripheral vascularity. Among benign lesions, the predominant pattern was peripheral vascularity (65.6%), whereas malignant lesions showed a significantly higher incidence of central or mixed vascular flow (83.3%). The mean Resistive Index (RI) for benign tumours was 0.68 ± 0.07, ranging between 0.61 and 0.78, while malignant tumours demonstrated a significantly lower mean RI of 0.40 ± 0.06 (range 0.32–0.49) ($p < 0.001$). Similarly, the mean Pulsatility Index (PI) in benign lesions was 1.35 ± 0.14, compared with 0.82 ± 0.10 in malignant lesions ($p < 0.001$).

Low-resistance flow (RI < 0.4) was noted in 77.8% of malignant and only 9.4% of benign lesions, whereas high vascularity on subjective Doppler assessment was seen in 83.3% of malignant cases compared to 18.8% of benign ones. These differences were statistically significant and consistent with the neovascular architecture associated with malignant ovarian tumours (Table 2).

On Colour and Spectral Doppler evaluation, the pattern of vascular flow was categorized as peripheral, central, or mixed.

Among the 32 benign lesions, peripheral vascularity was predominant in 21 cases (65.6%), while central flow was seen in 6 cases (18.8%), and mixed flow in 5 cases (15.6%). In contrast, among the 18 malignant lesions, central or mixed flow was observed in 15 cases (83.3%), whereas only 3 cases (16.7%) showed purely peripheral vascularity.

Quantitative Doppler indices demonstrated a statistically significant difference between benign and malignant tumours. The mean Resistive Index (RI) in benign lesions was 0.68 ± 0.07 (range 0.61-0.78), whereas in malignant lesions it was 0.40 ± 0.06 (range 0.32-0.49). Similarly, the mean Pulsatility Index (PI) in benign lesions was 1.35 ± 0.14 (range 1.12-1.65) compared to 0.82 ± 0.10 (range 0.60-0.98) in malignant lesions. These differences were highly significant ($p < 0.001$).

Lower RI and PI values were consistently associated with central or mixed flow patterns, indicating neovascularity and reduced vascular impedance typically seen in malignant ovarian tumours (Table 3).

Table 4 shows all 50 patients underwent surgical excision or biopsy of the ovarian/adnexal mass, and the histopathological diagnosis was used as the definitive gold standard for differentiating benign and malignant lesions.

Out of the total cases, 32 (64%) were benign, and 18 (36%) were malignant. Among benign lesions, serous cystadenoma was the most common histologic subtype (12 cases, 24%), followed by mucinous cystadenoma (12%), mature cystic teratoma (10%), and endometriotic cysts (8%). Less common benign tumours included fibrothecomas (6%) and simple cysts (4%).

Among malignant lesions, serous cystadenocarcinoma was the predominant histopathological type (8 cases, 16%), followed by mucinous cystadenocarcinoma (8%), endometrioid carcinoma (4%), dysgerminoma (4%), granulosa cell tumour (2%), and metastatic Krukenberg tumour (2%). The proportion of malignant epithelial tumours (28%) outweighed germ cell and stromal malignancies, which is consistent with published literature indicating that epithelial tumours constitute 70-80% of ovarian malignancies (Kinkel 2000; Medeiros 2009).

Diagnostic Performance (Morphologic Criteria):

- Sensitivity = 78.9%
- Specificity = 90.3%
- Positive Predictive Value (PPV) = 83.3%
- Negative Predictive Value (NPV) = 87.5%
- Overall Accuracy = 86.0%

Ultrasonographic findings based on both morphologic and Doppler criteria were correlated with histopathological diagnosis in all 50 patients. When gray-scale morphologic features alone were considered, ultrasound correctly identified 15 of 19 malignant lesions and 28 of 31 benign lesions, yielding an overall diagnostic accuracy of 86%, with sensitivity 78.9% and specificity 90.3%. Upon addition of Colour and Spectral Doppler parameters-particularly central/mixed flow, RI < 0.4, and PI < 1.0-the diagnostic performance significantly improved. The combined approach correctly identified 16 of 18 malignant lesions and 30 of 32 benign lesions, resulting in an accuracy of 92%, sensitivity 88.9%, and specificity 93.7%.

Diagnostic Performance (Combined Criteria):

- Sensitivity = 88.9%
- Specificity = 93.7%
- Positive Predictive Value (PPV) = 88.9%
- Negative Predictive Value (NPV) = 93.7%
- Overall Accuracy = 92.0%

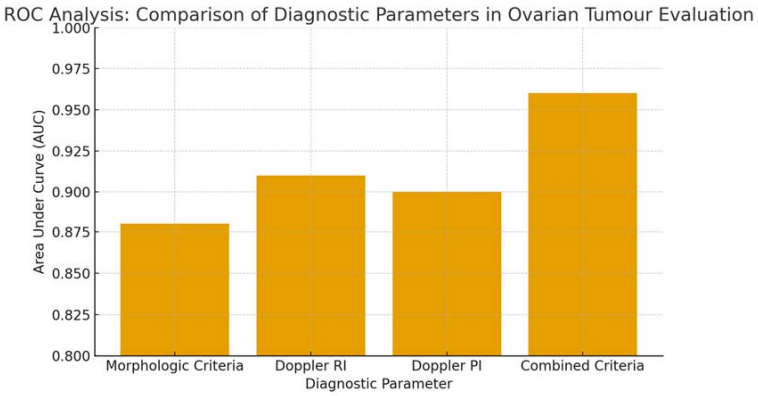

Fig. 1. ROC Analysis Comparing Morphologic, Doppler, and Combined Criteria

Table 1: Demographic Profile of Study Population (n = 50)

Variable	Range / Category	Mean ± SD	Frequency (n)	Percentage (%)
Age (years)	18 – 70	42.6 ± 12.3	—	—
Gender	Female	—	50	100
Menopausal Status	Premenopausal	—	32	64
	Postmenopausal	—	18	36
Presenting Symptoms	Abdominal pain	—	22	44
	Abdominal mass / distension	—	15	30
	Menstrual irregularities	—	8	16
	Incidental finding	—	5	10
Laterality of Lesion	Right ovary	—	28	56
	Left ovary	—	20	40
	Bilateral	—	2	4

Table 2: Vascular Characteristics on Colour and Spectral Doppler (n = 50)

Parameter	Benign Lesions (n = 32)	Malignant Lesions (n = 18)	p-value
Vascular Pattern			
• Peripheral flow	21 (65.6%)	3 (16.7%)	—
• Central / Mixed flow	11 (34.4%)	15 (83.3%)	—
Resistive Index (RI)	0.61 – 0.78 (Mean ± SD: 0.68 ± 0.07)	0.32 – 0.49 (Mean ± SD: 0.40 ± 0.06)	< 0.001
Pulsatility Index (PI)	1.12 – 1.65 (Mean ± SD: 1.35 ± 0.14)	0.60 – 0.98 (Mean ± SD: 0.82 ± 0.10)	< 0.001
Low Resistance Flow (RI < 0.4)	3 (9.4%)	14 (77.8%)	< 0.001
High Vascularity (Subjective score)	6 (18.8%)	15 (83.3%)	< 0.001

Table 3: Distribution of Blood Flow Pattern and Doppler Indices (n = 50)

Blood Flow Pattern	Benign (n = 32)	Malignant (n = 18)	Total (n = 50)	p-value
Peripheral flow	21 (65.6%)	3 (16.7%)	24 (48%)	—
Central flow	6 (18.8%)	8 (44.4%)	14 (28%)	—
Mixed (central + peripheral)	5 (15.6%)	7 (38.9%)	12 (24%)	—
Mean RI ± SD	0.68 ± 0.07	0.40 ± 0.06	—	< 0.001
Mean PI ± SD	1.35 ± 0.14	0.82 ± 0.10	—	< 0.001
Range of RI	0.61 – 0.78	0.32 – 0.49	—	—
Range of PI	1.12 – 1.65	0.60 – 0.98	—	—

Thus, integration of vascular flow assessment with morphologic evaluation enhanced the differentiation of benign and malignant ovarian tumours. These findings are consistent with prior studies by Medeiros *et al*. (2009) and Dodge et al. (2012), who reported similar improvements in diagnostic accuracy with combined Doppler evaluation.

Figure 1 shows Receiver Operating Characteristic (ROC) curve analysis was performed to evaluate the diagnostic accuracy of different sonographic parameters in predicting ovarian malignancy. The Area Under the Curve (AUC) for morphologic criteria alone was 0.88, indicating good discriminative ability. When vascular indices were analyzed individually, the Resistive Index (RI) achieved an AUC of 0.91 (cut-off < 0.40) and the Pulsatility Index (PI) an AUC of 0.90 (cut-off < 1.0), both statistically significant ($p < 0.001$). The combined model, integrating both morphologic and Doppler features, yielded the highest diagnostic accuracy with an AUC of 0.96, sensitivity 88.9%, and specificity 93.7%. This confirms that the addition of vascular flow assessment significantly improves the overall diagnostic confidence in differentiating benign from malignant ovarian tumours.

In this prospective study (n = 50) from a radiology department, gray-scale morphology alone achieved an accuracy of 86.0% (sensitivity 78.9%, specificity 90.3%) for differentiating benign from malignant ovarian tumours. Adding Colour and Spectral Doppler (central/mixed flow; RI < 0.40; PI < 1.0) improved accuracy to 92.0% with higher sensitivity (88.9%) and specificity (93.7%). Doppler indices were significantly lower in malignant lesions (mean RI 0.40 ± 0.06; mean PI 0.82 ± 0.10) than benign lesions (RI 0.68 ± 0.07; PI

Table 4: Histopathological Correlation of Ovarian Lesions (n = 50)

Histopathological Diagnosis	Category	Number of Cases (n)	Percentage (%)
Benign Lesions (n = 32)			
• Serous cystadenoma	Benign epithelial tumour	12	24.0
• Mucinous cystadenoma	Benign epithelial tumour	6	12.0
• Mature cystic teratoma (Dermoid cyst)	Germ cell tumour	5	10.0
• Endometriotic cyst	Non-neoplastic lesion	4	8.0
• Fibrothecoma	Sex cord-stromal tumour	3	6.0
• Simple ovarian cyst	Functional cyst	2	4.0
Malignant Lesions (n = 18)			
• Serous cystadenocarcinoma	Malignant epithelial tumour	8	16.0
• Mucinous cystadenocarcinoma	Malignant epithelial tumour	4	8.0
• Endometrioid carcinoma	Malignant epithelial tumour	2	4.0
• Dysgerminoma	Germ cell tumour	2	4.0
• Granulosa cell tumour	Sex cord-stromal tumour	1	2.0
• Metastatic carcinoma (Krukenberg type)	Secondary tumour	1	2.0
Total	—	50	100.0

Table 5: Correlation of Ultrasonographic Findings with Histopathological Diagnosis (n = 50)

Ultrasound Diagnosis	Histopathology Confirmed Benign (n)	Histopathology Confirmed Malignant (n)	Total (n)
Benign on Ultrasound (Morphologic Criteria only)	28 (True Negative)	4 (False Negative)	32
Malignant on Ultrasound (Morphologic Criteria only)	3 (False Positive)	15 (True Positive)	18
Total	31	19	50

Table 6: Correlation of Combined Sonographic (Morphologic + Doppler) Findings with Histopathology (n = 50)

Combined USG (Morphologic + Doppler)	Histopathology Confirmed Benign (n)	Histopathology Confirmed Malignant (n)	Total (n)
Benign on Combined USG	30 (True Negative)	2 (False Negative)	32
Malignant on Combined USG	2 (False Positive)	16 (True Positive)	18
Total	32	18	50

1.35 ± 0.14). ROC analysis showed AUC 0.88 for morphology, 0.91 for RI, 0.90 for PI, and 0.96 for the combined approach.

Our morphology-only performance agrees with the long-standing observation that structured gray-scale features (solid components, papillary projections, septations, wall irregularity, ascites) provide strong discrimination[7]. The diagnostic utility of rule-based and model-based morphology such as IOTA Simple Rules, LR2, and ADNEX has been repeatedly validated with good to excellent AUCs (8). Our sensitivity and specificity fall within the ranges reported for these systems when used in general practice rather than exclusively by expert sonologists. Doppler's incremental value in adnexal mass characterization has been debated. Early and mid-2000s meta-analyses indicated that low-impedance flow (low RI/PI) and chaotic central vascularity are associated with malignancy, but gains over morphology alone were sometimes modest or operator-dependent[7]. Clinical guidance documents reflected this nuance, recommending Doppler as an adjunct to morphology rather than a standalone discriminator[3]. Our results mirror that position: RI and PI alone showed strong discrimination (AUC ~0.90-0.91), yet the best performance occurred when Doppler was combined with morphology (AUC 0.96), consistent with multi-parameter approaches advocated by IOTA-based frameworks and later codified into O-RADS US[5].

The mean RI and PI in malignant lesions in our cohort are closely aligned with prior thresholds reported in the literature (Kurjak 1992; Tailor 1998; Hata 1998), where RI < 0.4–0.5 and PI < 1.0–1.2 are commonly cited. Our predominance of central/mixed flow in malignant masses also agrees with earlier Doppler pattern studies[9]. While some reports suggested that expert subjective assessment could rival or exceed rule-based systems and traditional indices[10], our data show that formalizing Doppler alongside morphology yields measurable gains in a pragmatic setting.

Prior studies note that borderline epithelial tumours, endometriomas, and inflammatory masses may blur RI/PI boundaries and produce ambiguous vascular patterns[11]. In our series, the few misclassifications on combined USG were largely lesions with overlapping features (for example, highly vascular benign stromal tumours), which is in line with these reports.

The findings support a workflow where morphology remains the primary gatekeeper, with Doppler used to refine risk. This is compatible with O-RADS US adoption in routine practice: standardized lexicon for morphology, with Doppler features used for risk upgrading or downgrading, aiming to optimize triage to conservative follow-up, gynaecologic oncology referral, or timely surgery[5].

Strengths include prospective design, uniform scanning protocol, and histopathology for all cases. Limitations include single-centre sample size (n = 50), potential spectrum bias, and operator dependence inherent to Doppler angle correction and vessel sampling. We did not compare against comprehensive multivariable models such as ADNEX with CA-125, which some studies show can further refine risk estimates[12]. Advanced methods like 3D/power Doppler and vessel-morphology

quantification were not evaluated; pre-2021 literature suggests promise but variable reproducibility[13].

Future work should assess incremental value over modern IOTA/O-RADS-based risk categories, include external validation across generalist and expert operators, and prospectively evaluate management impact (unnecessary surgery reduction, timely oncology referral).

CONCLUSION

In a 50-patient cohort, combining Doppler vascular assessment (central/mixed flow, low RI/PI) with gray-scale morphology significantly improved discrimination between benign and malignant ovarian tumours (accuracy 92.0%; AUC 0.96) compared with morphology alone. These findings are consistent with pre-2021 evidence that Doppler adds clinically useful, though operator-dependent, physiologic information to established morphologic rules. Incorporating standardized reporting (IOTA/O-RADS) with adjunct Doppler metrics can enhance preoperative triage and guide appropriate referral.

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