Vol. 5 No. 1 (2026)

Pakistan Journal of Medical & Cardiological Review

https://pakjmcr.com/index.php/1/about

Online ISSN 3007-2387 | Print ISSN 3007-2379

Comparison of Diagnostic Accuracy of Doppler Ultrasound in Differentiating Benign and Malignant Uterine Masses with Histopathology

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Keywords: Uterine Neoplasms; Ultrasonography, Doppler, Color; Leiomyoma; Histological Techniques; Sensitivity and Specificity; Diagnosis, Differential; Female; Pelvic Neoplasms

Received on 01 Mar 2026
Accepted on 21 Mar 2026
Published on 01 Apr 2026

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Abstract

Abstract

Background: Uterine masses are common gynecological findings and include both benign lesions, such as leiomyomas, and malignant tumors, including endometrial carcinoma and uterine sarcomas. Because benign and malignant uterine masses may present with overlapping clinical and grayscale sonographic features, accurate preoperative differentiation remains challenging. Doppler ultrasound provides additional vascular and hemodynamic information that may improve diagnostic discrimination. Objective: To evaluate the diagnostic accuracy of Doppler ultrasound in differentiating benign and malignant uterine masses using histopathology as the reference standard. Methodology: A cross-sectional analytical study was conducted at Social Security Hospital and Tahir Diagnostic Centre, Okara, over four months. Sixty female patients with clinically suspected or sonographically detected uterine masses were included through convenience sampling. All patients underwent grayscale and Doppler ultrasonography using transabdominal and/or transvaginal probes. Doppler assessment included vascularity pattern, resistance index, pulsatility index, and blood flow characteristics. Final diagnosis was confirmed by biopsy or surgical histopathology. Data were analyzed using SPSS version 25. Sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy were calculated. Conclusion: Doppler ultrasound demonstrated high diagnostic accuracy in differentiating benign from malignant uterine masses and may serve as a valuable non-invasive adjunct in preoperative evaluation. However, due to possible overlap in Doppler features and the presence of false-negative cases, Doppler findings should not be used alone. They should be interpreted alongside grayscale ultrasound, clinical parameters, and histopathological confirmation.

Introduction

Uterine masses are a frequent clinical problem in gynecology and include a broad spectrum of benign and malignant pathologies (1). Benign lesions, particularly uterine leiomyomas, are far more common and may affect nearly three-quarters of women over the course of life, whereas malignant uterine tumors such as endometrial carcinoma and uterine sarcomas are less common but clinically far more consequential because delayed diagnosis can adversely affect treatment and prognosis (2). Endometrial cancer remains the most common gynecologic malignancy in high-income settings, while uterine sarcomas are rare, aggressive mesenchymal tumors with substantial diagnostic difficulty in routine practice (3).

The main challenge in evaluating uterine masses is that benign and malignant lesions may present with overlapping symptoms and imaging appearances (4). Patients commonly report abnormal uterine bleeding, pelvic pain, pelvic pressure, infertility, or rapid uterine enlargement, but these features alone do not reliably discriminate leiomyoma from sarcoma or other malignant disease. Ultrasound is therefore the first-line imaging modality because it is widely available, inexpensive, non-ionizing, and well suited for real-time pelvic assessment. Conventional grayscale ultrasound is highly useful for identifying lesion size, number, location, echotexture, and degenerative change; however, its specificity for malignancy remains limited when atypical or degenerated leiomyomas mimic malignant morphology (5).

Doppler ultrasound was introduced to address this limitation by adding functional assessment of tumor vascularity to morphological evaluation (6). Color and spectral Doppler can characterize vascular architecture and quantify hemodynamic indices such as the resistance index (RI) and pulsatility index (PI) (7). From a pathophysiological standpoint, malignant tumors tend to demonstrate neoangiogenesis, chaotic vessel architecture, and lower vascular resistance, producing lower RI and PI values and often more prominent central or mixed vascularity. In contrast, benign leiomyomas more often show peripheral vascularity and relatively higher impedance flow, although overlap can occur, especially in cellular, degenerative, or inflamed fibroids (8).

Early work by Kurjak and Zalud suggested that transvaginal color Doppler could assist in differentiating benign from malignant uterine tumors. Subsequent studies refined this concept (9). Szabó et al. demonstrated that sarcomas generally had lower intratumoral RI and PI and higher peak systolic velocity than leiomyomas, although they also emphasized that Doppler indices alone were insufficient because some benign leiomyomas with necrotic or degenerative change showed similar flow patterns (10). Exacoustos et al. later reported that suspicious findings such as large tumor size, cystic degeneration, and increased peripheral and central vascularity may improve preoperative suspicion for leiomyosarcoma, especially when grayscale and Doppler features are interpreted together rather than in isolation (11).

More recent evidence has strengthened but also nuanced the role of ultrasound in this differential diagnosis. A large multicenter study by Ludovisi et al. found that uterine sarcomas typically appear as solid, inhomogeneous masses, often with irregular cystic areas and moderate-to-rich vascularization (12). De Bruyn et al., using standardized MUSA terminology, further showed that contemporary ultrasound descriptors can improve consistency in distinguishing leiomyoma from sarcoma (13). At the same

time, a systematic review and meta-analysis by Raffone et al. concluded that ultrasound has only moderate overall diagnostic accuracy for differentiating uterine leiomyomas from sarcomas, with pooled sensitivity of 76% and specificity of 89%, indicating that ultrasound is more useful for strengthening suspicion than for definitively excluding malignancy. This explains why histopathology remains the diagnostic gold standard and why imaging findings must be integrated with age, menopausal status, symptoms, and lesion morphology (14).
Current research is therefore moving toward multimodal and algorithm-based risk stratification rather than reliance on single Doppler thresholds. Ciccarone et al. recently proposed a clinical-ultrasound algorithm for identifying uterine sarcoma and smooth muscle tumors of uncertain malignant potential in patients with myometrial lesions, reflecting a shift toward structured preoperative assessment. Even so, there remains a need for institution-specific and population-specific validation of Doppler ultrasound against histopathology, particularly in routine clinical settings where access to advanced MRI, expert gynecologic oncology imaging, and standardized reporting may vary.
Aims And Objectives: To evaluate the diagnostic accuracy of doppler ultrasound in differentiating between benign and malignant uterine cancers using histology as the reference standard.

Methodology:

This study was designed as a cross-sectional analytical study to determine the diagnostic accuracy of Doppler ultrasonography in differentiating benign from malignant uterine masses, using histopathology as the reference standard. The study was conducted at Social Security Hospital and Tahir Diagnostic Centre near DHQ Road, Okara, over a duration of four months after approval of the synopsis. The target population comprised female patients presenting with clinically suspected or sonographically detected uterine masses. A total of 60 patients were included in the study. According to the thesis, the sample size was estimated using the standard formula $n = Z^2P(1-P)/d^2$, with a 95% confidence level, margin of error of 5%, and an assumed prevalence of 0.04. Patients were recruited through a convenience sampling technique until the required sample size was achieved.
Female patients of any age were considered eligible if they had a uterine mass identified on clinical examination or sonography and were willing to undergo Doppler ultrasonography followed by biopsy or surgical excision. Patients were excluded if they had pregnancy-related uterine changes, a previous history of pelvic surgery affecting the uterus, refusal to undergo ultrasound or surgical intervention, or any contraindication to biopsy or surgery.
Ultrasound examinations were performed using a high-resolution ultrasound machine equipped with transabdominal and transvaginal probes ranging from 5 to 9 MHz, with integrated color and spectral Doppler capabilities for vascular assessment. For transabdominal scanning, patients were advised to maintain a slightly filled bladder to improve pelvic visualization, whereas for transvaginal scanning, patients were instructed to empty their bladder before the examination. Depending on the clinical requirement, transabdominal and/or transvaginal ultrasonography was performed in each case. Initially, grayscale ultrasonography was used to evaluate the lesion with respect to its location, size, echotexture, margins, internal architecture, and the presence of solid or cystic components. This was followed by Doppler assessment to evaluate the vascular pattern of the lesion. Color Doppler was used to classify vascularity as central, peripheral, or mixed, while spectral Doppler was used to obtain quantitative hemodynamic indices, specifically the Resistance Index (RI) and Pulsatility Index (PI).
A structured proforma was used for systematic data recording. Demographic and clinical variables included age, uterine size, number of masses, parity, and gravidity.

Sonographic variables included lesion margins, lesion position, echogenicity, myometrial echotexture, and the presence of lacunae or hypoechoic spaces within the lesion. Doppler variables included vascularity pattern, resistance index, pulsatility index, and qualitative blood flow characteristics. After imaging, all patients underwent either biopsy or surgical excision as part of their clinical management, and the tissue specimens were sent to the histopathology laboratory for definitive diagnosis. Histopathological examination served as the gold standard for classifying each lesion as benign or malignant, and Doppler findings were compared against these final tissue-based results.

Data were analyzed using SPSS version 25. Descriptive statistics were calculated for both patient demographics and lesion characteristics. Continuous variables were summarized as mean and standard deviation, whereas categorical variables were presented as frequencies and percentages. Using histopathology as the reference standard, the diagnostic performance of Doppler ultrasonography was assessed by calculating sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy. In addition, the association between Doppler ultrasound findings and histopathological diagnosis was evaluated using the Chi-square test, while the relationship between Doppler parameters and histopathological outcomes was assessed using Spearman's correlation analysis. A p-value of less than 0.05 was considered statistically significant for all inferential analyses.

Results:

A total of 60 female patients with uterine masses were included in the study. The patients ranged in age from 25 to 65 years, with a mean age of 42.6 ± 10.3 years. The largest proportion of patients belonged to the 41–50 years age group (30.0%), followed by the 31–40 years group (23.3%). Histopathology showed that 38 cases (63.3%) were benign and 22 cases (36.7%) were malignant. On Doppler ultrasonography, 40 masses (66.7%) were classified as benign and 20 (33.3%) as malignant. Overall, the study population was predominantly middle-aged, and benign uterine masses were more frequent than. Most patients were in the **41–50 years** age group, showing that uterine masses were most common in middle-aged women in this sample. Mean age was **42.6 ± 10.3 years**.

Final histopathological diagnosis:

This table shows the final diagnosis of uterine masses based on histopathology, which was used as the **gold standard** in the study. Out of 60 cases, **38 (63.3%)** were confirmed as benign and **22 (36.7%)** as malignant. These findings show that benign uterine masses were more common than malignant ones in the studied population. This distribution is important because it provides the true disease status against which the Doppler ultrasound findings were compared.

Histopathology diagnosis	**n**	**%**
Benign masses	38	63
Malignant masses	22	37
Total	60	100

Doppler ultrasound diagnosis of uterine masses:

This table summarizes how Doppler ultrasound categorized the uterine masses before histopathological confirmation. According to Doppler findings, **40 cases (66.7%)** were labeled as benign and **20 cases (33.3%)** as malignant. The table reflects the initial imaging-based impression of the lesions and provides the basis for later comparison with histopathology to determine how accurately Doppler ultrasound differentiated between benign and malignant uterine masses.

Doppler ultrasound result	n	%
Benign	40	66.7
Malignant	20	33.3
Total	60	100

Comparison of Doppler ultrasound with histopathology:
This table compares Doppler ultrasound results directly with histopathological findings and shows the number of true positives, true negatives, false positives, and false negatives. Doppler ultrasound correctly identified 19 malignant cases and 37 benign cases, while 1 benign case was incorrectly labeled as malignant and 3 malignant cases were missed. This table is the core diagnostic comparison of the study because all performance measures, including sensitivity, specificity, and overall accuracy, are derived from these values. It also demonstrates that Doppler ultrasound had a high level of agreement with the final tissue diagnosis.

Doppler ultrasound result	Malignant on histopathology	Benign on histopathology
Malignant	19 (True positive)	1 (False positive)
Benign	3 (False negative)	37 (True negative)

Diagnostic performance of Doppler ultrasound:
This table presents the main diagnostic accuracy measures of Doppler ultrasound using histopathology as the reference standard. The sensitivity of **86.4%** shows that Doppler ultrasound was effective in detecting most malignant masses, while the specificity of **97.4%** indicates excellent ability to correctly identify benign lesions. The **positive predictive value (95.0%)** means that most lesions diagnosed as malignant on Doppler were truly malignant, whereas the **negative predictive value (92.5%)** indicates that lesions classified as benign were usually benign on histopathology. The overall diagnostic accuracy of **93.3%** confirms that Doppler ultrasound performed strongly as a non-invasive diagnostic tool in this study.

Parameter	Value (%)
Sensitivity	86.4
Specificity	97.4
Positive predictive value (PPV)	95
Negative predictive value (NPV)	92.5
Overall diagnostic accuracy	93.3

Main Doppler flow characteristics in benign and malignant uterine masses:
This table outlines the characteristic Doppler flow patterns seen in benign and malignant uterine masses. Benign lesions generally showed mild or peripheral vascularity, higher resistance index, higher pulsatility index, and a more regular blood flow pattern. In contrast, malignant lesions were characterized by marked central vascularity, low resistance index, low pulsatility index, and irregular or chaotic blood flow. These findings are consistent with tumor angiogenesis in malignant lesions, where abnormal neovascularization leads to increased central blood supply and lower vascular resistance. Therefore, this table highlights the physiological basis for using Doppler ultrasound to distinguish between benign and malignant uterine masses.

Doppler parameter	Benign masses	Malignant masses
Vascularity pattern	Mild/peripheral	Marked/central
Resistive index (RI)	High (>0.5)	Low (<0.4)
Pulsatility index (PI)	High	Low
Blood flow pattern	Regular	Irregular/chaotic

Discussion:

The present study demonstrates that Doppler ultrasonography has high diagnostic accuracy (93.3%), with sensitivity of 86.4% and specificity of 97.4%, in differentiating benign from malignant uterine masses when compared with histopathology. These findings indicate that Doppler imaging is particularly effective in correctly identifying benign lesions, thereby reducing false-positive diagnoses and unnecessary surgical interventions. Similar diagnostic performance has been reported in previous studies, where Doppler ultrasound improved specificity by incorporating vascular parameters alongside grayscale morphology, especially in distinguishing leiomyomas from malignant uterine tumors.

The Doppler flow characteristics observed in this study—namely central vascularity, low resistance index (RI), low pulsatility index (PI), and chaotic flow in malignant lesions, compared to peripheral vascularity and higher impedance flow in benign lesions—are consistent with the pathophysiological basis of tumor angiogenesis. Malignant tumors typically develop abnormal, low-resistance vascular networks, which are detectable on Doppler interrogation. These findings align with earlier work by Kurjak et al. and Szabó et al., who reported that reduced RI and PI values and increased central vascularity are indicative of malignancy, although overlap between benign and malignant patterns may occur in certain cases.

Despite the strong performance, the presence of false-negative cases highlights a key limitation of Doppler ultrasonography. Some malignant lesions may mimic benign vascular patterns, particularly in cases of degenerative leiomyomas or tumors with heterogeneous architecture. This observation is consistent with previous literature suggesting that Doppler indices alone cannot provide absolute diagnostic certainty and should be interpreted in conjunction with grayscale findings and clinical variables. Meta-analyses have also shown that while ultrasound demonstrates high specificity, its sensitivity may vary due to such overlaps, emphasizing the continued role of histopathology as the gold standard.

Furthermore, the demographic distribution in this study, with a predominance of patients in the middle-aged group (41–50 years), reflects known epidemiological patterns of uterine pathology. The increasing likelihood of malignancy with age underscores the importance of integrating patient demographics into imaging interpretation. Although Doppler ultrasound showed strong statistical association with histopathological outcomes ($p < 0.001$), factors such as small sample size, convenience sampling, and operator dependency may influence generalizability. Therefore, while Doppler ultrasonography provides valuable functional insight into lesion vascularity, it should be considered part of a multimodal diagnostic approach rather than a standalone tool.

Conclusion:

Doppler ultrasonography demonstrates a high level of diagnostic efficacy in differentiating benign from malignant uterine masses, combining strong specificity, reliable sensitivity, and excellent overall accuracy with the ability to non-invasively characterize tumor vascularity and hemodynamics. By revealing physiologically relevant features such as central neovascularization, reduced vascular resistance, and disorganized blood flow, Doppler imaging extends beyond structural assessment and provides meaningful insight into tumor biology, thereby enhancing preoperative risk stratification and clinical decision-making. However, given the potential for overlap in vascular patterns and the occurrence of false-negative cases, Doppler findings must be interpreted within a comprehensive diagnostic framework that includes grayscale imaging, patient demographics, and histopathological confirmation. Consequently, Doppler ultrasonography should be regarded as a powerful adjunctive modality that bridges morphological and functional imaging, contributing to more precise, evidence-based management of uterine masses while supporting optimized surgical planning and improved patient outcomes.

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