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DIAGNOSTIC ACCURACY OF TRANSVAGINAL ULTRASOUND WITH COLOR DOPPLER IN DIFFERENTIATING BENIGN VS MALIGNANT ADNEXAL MASSES IN PREGNANCY

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ABSTRACT

Background: Adnexal masses are increasingly detected during pregnancy due to the widespread use of routine obstetric ultrasonography. Transvaginal ultrasonography (TVUS) combined with Color Doppler imaging has become the preferred first-line imaging modality.

Objective: To determine the diagnostic accuracy of transvaginal ultrasonography combined with Color Doppler in differentiating benign from malignant adnexal masses during pregnancy using histopathological examination as the reference standard.

Methods: A prospective observational diagnostic accuracy study was conducted among pregnant women diagnosed with adnexal masses at a tertiary care teaching hospital. Eligible participants who underwent transvaginal ultrasonography with Color Doppler evaluation were consecutively enrolled. Sonographic characteristics were systematically documented. The diagnostic performance of TVUS combined with Color Doppler was evaluated by calculating sensitivity, specificity, positive predictive value, negative predictive value and overall diagnostic accuracy.

Results: A total of 132 pregnant women with sonographically diagnosed adnexal masses were included in the study. Histopathological examination identified 118 (89.4%) benign and 14 (10.6%) malignant lesions. The imaging modality demonstrated a sensitivity of 92.9%, specificity of 95.8%, positive predictive value of 72.2%, negative predictive value of 99.1%, and an overall diagnostic accuracy of 95.5%.

Conclusion: Transvaginal ultrasonography combined with Color Doppler demonstrated excellent diagnostic performance in differentiating benign from malignant adnexal masses during pregnancy. As a safe, non-invasive, readily available, and cost-effective imaging modality, TVUS with Color Doppler can support timely referral, individualized clinical management, and improved maternal and fetal outcomes.

KEYWORDS: Adnexal mass; Pregnancy; Ovarian tumor; Transvaginal ultrasonography; Color Doppler; Diagnostic accuracy

INTRODUCTION

Adnexal masses are among the most frequently encountered gynecological abnormalities during pregnancy, primarily because of the widespread use of routine obstetric ultrasonography during the first trimester. Their reported incidence ranges from 0.2% to 8.8%, depending on the study population, gestational age at screening, and imaging protocols employed. Most adnexal masses detected during pregnancy are functional ovarian cysts, including corpus luteum and follicular cysts, which typically resolve spontaneously as pregnancy progresses. However, approximately 1–8% of persistent adnexal masses are malignant and therefore require prompt diagnosis and appropriate management to optimize both maternal and fetal outcomes. Accurate differentiation between benign and malignant adnexal lesions remains a critical component of antenatal care because delayed diagnosis may result in disease progression, whereas unnecessary surgical intervention may increase the risks of miscarriage, preterm labor, and fetal morbidity (1,2).

The increasing availability and improved quality of prenatal ultrasonography have substantially enhanced the detection of asymptomatic adnexal masses. Most lesions are identified incidentally during routine fetal viability or anomaly scans before the onset of clinical symptoms. Although most of these lesions remain benign throughout pregnancy, certain pathological entities including epithelial ovarian tumors, borderline ovarian tumors, germ cell tumors, sex cord-stromal tumors, and metastatic ovarian malignancies—require early recognition because maternal prognosis is closely associated with the stage of disease at diagnosis. Furthermore, the physiological and hormonal changes associated with pregnancy may alter the morphology and vascularity of ovarian lesions, making sonographic interpretation more challenging than in non-pregnant women (3).

Clinical assessment alone has limited value in distinguishing benign from malignant adnexal masses during pregnancy because symptoms such as pelvic pain, abdominal discomfort, nausea, vomiting, and abdominal distension frequently overlap with the normal physiological changes of pregnancy. Similarly, serum tumor markers including cancer antigen 125 (CA-125), human epididymis protein-4 (HE4), alpha-fetoprotein (AFP), lactate dehydrogenase (LDH), and beta-human chorionic gonadotropin (β-hCG) may be physiologically elevated during pregnancy, thereby reducing their diagnostic specificity. Consequently, imaging has become the cornerstone for evaluating adnexal masses in pregnant women, allowing accurate characterization of lesion morphology while avoiding fetal exposure to ionizing radiation (4).

Transvaginal ultrasonography (TVUS) is widely regarded as the first-line imaging modality for evaluating adnexal masses because of its excellent spatial resolution, accessibility, cost-effectiveness, and well-established safety profile during pregnancy. Compared with transabdominal ultrasonography, TVUS provides superior visualization of ovarian morphology during early gestation, enabling detailed assessment of lesion size, internal architecture, septations, papillary projections, mural nodules, wall thickness, echogenicity, and associated pelvic free fluid. Several sonographic features including irregular multilocular-solid morphology, papillary excrescences, thick septations (>3 mm), solid components, bilateral ovarian involvement, ascites, and peritoneal nodules have consistently been associated with an increased likelihood of malignancy. In contrast, unilocular thin-walled cysts containing anechoic fluid are generally considered benign and frequently resolve spontaneously during pregnancy (5).

Although grayscale ultrasonography remains the primary imaging modality for the evaluation of adnexal masses, morphological assessment alone may not reliably differentiate benign from malignant lesions during pregnancy. Pregnancy-related changes, including decidualization of endometriomas, hemorrhagic corpus luteum cysts, and mature cystic teratomas, may closely mimic the sonographic appearance of ovarian malignancies, thereby reducing diagnostic specificity. Consequently, Color Doppler ultrasonography has become an important adjunct to conventional grayscale imaging by enabling the assessment of tumor vascularity and blood flow characteristics associated with neoplastic angiogenesis. Malignant ovarian tumors typically exhibit increased central vascularity, disorganized vascular architecture, low vascular resistance, and higher peak systolic velocities due to the formation of abnormal tumor neovasculature. Accordingly, Doppler-derived parameters, including the Resistance Index (RI), Pulsatility Index (PI), and Peak Systolic Velocity (PSV), have been extensively investigated as valuable imaging biomarkers for differentiating benign from malignant adnexal lesions (6,7). Over the past two decades, several standardized ultrasound-based prediction models have been developed to improve the diagnostic accuracy and consistency of adnexal mass evaluation. Among the most widely adopted are the International Ovarian Tumor Analysis (IOTA) Simple Rules**,** the Assessment of Different NEoplasias in the adneXa (ADNEX) model**,** and the Ovarian-Adnexal Reporting and Data System (O-RADS)**.** These models have demonstrated excellent diagnostic performance in non-pregnant women by combining morphological and Doppler ultrasound features with standardized risk stratification criteria. Meta-analyses have reported sensitivities exceeding 90% for the ADNEX model and high specificity for the IOTA Simple Rules when histopathological findings are used as the reference standard. However, these predictive models have not been adequately validated in pregnant populations because pregnancy-associated physiological alterations may substantially modify ovarian morphology and Doppler vascularity, thereby limiting the direct applicability of findings derived from non-pregnant women (8).

Recent systematic reviews evaluating the diagnostic performance of ultrasonography during pregnancy have highlighted the limited availability of high-quality prospective diagnostic accuracy studies. Although the existing evidence suggests that ultrasonography demonstrates acceptable overall performance in differentiating benign from malignant adnexal masses, the pooled sensitivity remains lower than that reported in non-pregnant populations. This discrepancy is largely attributable to the small sample sizes, methodological heterogeneity, and limited number of prospective investigations employing standardized imaging protocols with histopathological confirmation. Consequently, robust evidence regarding the diagnostic accuracy of transvaginal ultrasonography combined with Color Doppler in pregnant women remains insufficient (1). Therefore, the present study aimed to determine the diagnostic accuracy of transvaginal ultrasonography combined with Color Doppler in differentiating benign from malignant adnexal masses during pregnancy using histopathological examination as the reference standard. It was hypothesized that the integration of morphological assessment with Doppler evaluation would improve diagnostic accuracy by enhancing the identification of malignant sonographic characteristics. The findings of this study are expected to strengthen the existing evidence base regarding this non-invasive imaging modality, facilitate early risk stratification, support informed clinical decision-making, reduce unnecessary surgical interventions, and ultimately contribute to improved maternal and fetal outcomes.

METHODOLOGY

A prospective observational diagnostic accuracy study was conducted in the Departments of Obstetrics and Gynecology and Radiology at a tertiary care teaching hospital in Pakistan over a 12-month period. The study was designed to evaluate the diagnostic accuracy of transvaginal ultrasonography (TVUS) combined with Color Doppler imaging in differentiating benign from malignant adnexal masses during pregnancy, using histopathological

examination as the reference (gold) standard. Pregnant women who presented to the antenatal outpatient department, emergency department, or obstetric wards with ultrasonographically diagnosed adnexal masses were screened for eligibility. Consecutive sampling was employed to recruit eligible participants until the required sample size was achieved, thereby minimizing selection bias and enhancing the representativeness of the study population.

The sample size was calculated using Buderer's formula for diagnostic accuracy studies based on the anticipated sensitivity of transvaginal ultrasonography combined with Color Doppler, the estimated prevalence of malignant adnexal masses during pregnancy, a 95% confidence level, and a 5% margin of error. The minimum required sample size was calculated to be 132 participants. Ethical approval was obtained from the Institutional Review Board (IRB) of the participating institution before the commencement of the study. Written informed consent was obtained from all eligible participants before enrollment. The study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, and participant confidentiality was maintained throughout the study. Pregnant women aged 18 years or older with singleton pregnancies and ultrasonographically confirmed adnexal masses who provided written informed consent were included in the study. Women with ectopic pregnancies, previously diagnosed ovarian malignancies, incomplete imaging records, poor-quality ultrasound examinations, or those who declined participation or refused clinically indicated surgical management were excluded.

After obtaining written informed consent, baseline demographic and clinical information was collected using a predesigned structured data collection form. The recorded variables included maternal age, parity, gravidity, gestational age at diagnosis, presenting complaints, previous gynecological history, and relevant medical history. All ultrasonographic examinations were performed by experienced consultant radiologists or sonologists with a minimum of five years of experience in gynecological imaging. To minimize observer bias, all radiologists remained blind to the final histopathological diagnosis throughout the imaging assessment. Gray-scale transvaginal ultrasonography (TVUS) was performed to evaluate the morphological characteristics of each adnexal lesion. The sonographic parameters assessed included maximum lesion diameter, laterality, cyst wall thickness, internal echogenicity, locularity, septal thickness, papillary projections, mural nodules, solid components, calcifications, acoustic shadowing, and the presence of ascites or peritoneal deposits. Based on these morphological characteristics, each lesion was classified as a simple cystic, multilocular cystic, solid, or mixed cystic-solid adnexal mass.

Following grayscale evaluation, Color Doppler ultrasonography was performed to assess the vascular characteristics of each lesion. The Doppler examination evaluated vascular distribution, vascular density, and intralesional blood-flow patterns. Spectral Doppler waveform analysis was subsequently performed to determine the Resistance Index (RI), Pulsatility Index (PI), and Peak Systolic Velocity (PSV). Lesions demonstrating increased central vascularity, low vascular resistance, and abnormal intralesional blood-flow patterns were considered suggestive of malignant pathology. Based on the combined grayscale and Color Doppler findings, each adnexal lesion was prospectively classified as either benign or malignant before definitive clinical management.

The decision regarding conservative management or surgical intervention was made by a multidisciplinary team comprising obstetricians, gynecologic oncologists, and radiologists in accordance with institutional clinical guidelines. Patients presenting with persistent complex adnexal masses, symptomatic lesions, rapidly enlarging masses, or sonographic features suspicious of malignancy underwent surgical intervention during the second trimester whenever clinically feasible. When maternal or fetal conditions required an alternative approach, surgery was performed at the most appropriate gestational age based on multidisciplinary clinical judgment. Women diagnosed with uncomplicated simple cysts were managed conservatively through serial ultrasonographic follow-up throughout pregnancy, and postpartum surgical excision was performed when clinically indicated. Histopathological examination of all surgically excised specimens was performed by experienced histopathologists who remained blinded to the ultrasonographic findings. The histopathological diagnosis served as the reference (gold) standard for establishing the final diagnosis of each adnexal lesion and was subsequently compared with the ultrasonographic findings to determine the diagnostic accuracy of transvaginal ultrasonography combined with Color Doppler.

Data were entered and analyzed using SPSS 29.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro–Wilk test**.** Normally distributed continuous variables were presented as mean ± standard deviation (SD)**,** whereas non-normally distributed variables were summarized as median and interquartile range (IQR)**.** Categorical variables were expressed as frequencies and percentages.

Comparisons between benign and malignant adnexal masses were performed using the independent-samples t-test for normally distributed continuous variables and the Mann–Whitney U test for non-normally distributed variables. Associations between categorical variables were evaluated using the Chi-square test **o**r Fisher's exact test**,** as appropriate.

Agreement between ultrasonographic findings and histopathological diagnoses was assessed using Cohen's kappa coefficient (κ**)** to determine the level of diagnostic agreement beyond chance.. Multivariable binary logistic regression analysis was performed to identify independent sonographic predictors of malignant adnexal masses after adjusting for potential confounding variables, including maternal age and lesion size. The results were reported as adjusted odds ratios (AORs) with corresponding 95% confidence intervals**.** A two-sided p-value of less than 0.05 was considered statistically significant for all analyses.

RESULTS

A total of 132 pregnant women with ultrasonographically diagnosed adnexal masses were included in the study. Histopathological examination confirmed that 118 (89.4%) lesions were benign, whereas 14 (10.6%) were malignant. The mean maternal age of the study participants was 29.8 ± 5.4 years (range: 19–41 years), and the mean gestational age at diagnosis was 15.6 ± 6.2 weeks**.** Most participants **(**54.5%**)** were between 25 and 34 years of age, while 62.9% were multigravida. Approximately half of the adnexal masses **(**50.8%**)** were diagnosed during the second trimester of pregnancy (Table 1).

Table 1. Baseline demographic and obstetric characteristics of the study population

Variable	Total (n=132)
Maternal age (years), Mean ± SD	29.8 ± 5.4
Age <25 years	31 (23.5%)
Age 25–34 years	72 (54.5%)
Age ≥35 years	29 (22.0%)
Primigravida	49 (37.1%)
Multigravida	83 (62.9%)
Gestational age (weeks), Mean ± SD	15.6 ± 6.2
First trimester	59 (44.7%)
Second trimester	67 (50.8%)
Third trimester	6 (4.5%)

Histopathological examination revealed that benign ovarian lesions constituted most adnexal masses diagnosed during pregnancy. Functional ovarian cysts were the most common histopathological diagnosis, accounting for 31.8% of all lesions, followed by corpus luteum cysts **(**17.4%**),** serous cystadenomas **(**14.4%**),** and mature cystic teratomas **(**11.4%**).** Among malignant lesions, epithelial ovarian carcinoma was the predominant histological subtype, followed by germ cell malignancies and other malignant ovarian tumors (Table 2)

Table 2. Histopathological diagnosis of adnexal masses

Histopathological diagnosis	Frequency (%)
Functional ovarian cyst	42 (31.8)
Corpus luteum cyst	23 (17.4)
Serous cystadenoma	19 (14.4)
Mucinous cystadenoma	13 (9.8)
Mature cystic teratoma	15 (11.4)
Endometrioma	6 (4.5)
Borderline ovarian tumor	4 (3.0)
Epithelial ovarian carcinoma	7 (5.3)
Germ cell malignancy	3 (2.3)
Other malignant tumors	4 (3.0)

Gray-scale transvaginal ultrasonography demonstrated significant differences in the morphological characteristics of benign and malignant adnexal masses. Malignant lesions were significantly larger than benign lesions (9.7 ± 2.8 cm vs. 5.8 ± 2.1 cm; $p < 0.001$**).** In addition, malignant masses more frequently exhibited solid components (92.9% vs. 16.1%**),** papillary projections **(**85.7% vs. 9.3%**),** thick septations **(**78.6% vs. 14.4%**),** bilateral ovarian involvement **(**42.9% vs. 11.0%**),** and ascites **(**57.1% vs. 3.4%**).** All these sonographic characteristics demonstrated statistically significant associations with malignant pathology **(**$p < 0.05$**)** (Table 3).

Table 3. Sonographic characteristics of benign and malignant adnexal masses

Variable	Benign (n=118)	Malignant (n=14)	p-value
Mean lesion size (cm)	5.8 ± 2.1	9.7 ± 2.8	<0.001
Solid component	19 (16.1%)	13 (92.9%)	<0.001
Papillary projections	11 (9.3%)	12 (85.7%)	<0.001
Thick septations	17 (14.4%)	11 (78.6%)	<0.001
Bilateral lesions	13 (11.0%)	6 (42.9%)	0.006
Ascites	4 (3.4%)	8 (57.1%)	<0.001

Color Doppler evaluation further enhanced the differentiation between benign and malignant adnexal lesions by demonstrating distinct vascular characteristics. Malignant tumors showed significantly greater central vascularity

(92.9%) compared with benign lesions (15.3%), whereas peripheral vascularity was more commonly observed in benign masses (58.5% vs. 7.1%). Furthermore, malignant lesions demonstrated significantly lower mean Resistance Index (RI) and Pulsatility Index (PI) values, together with substantially higher Peak Systolic Velocity (PSV), indicating increased tumor vascularity and low-resistance blood flow associated with malignant angiogenesis. All Doppler parameters differed significantly between the two groups ($p < 0.001$) (Table 4).

Table 4. Color Doppler findings

Variable	Benign	Malignant	p-value
Central vascularity	18 (15.3%)	13 (92.9%)	<0.001
Peripheral vascularity	69 (58.5%)	1 (7.1%)	<0.001
RI	0.66 ± 0.08	0.42 ± 0.05	<0.001
PI	1.34 ± 0.29	0.81 ± 0.18	<0.001
PSV (cm/s)	16.2 ± 5.8	32.5 ± 8.4	<0.001

Comparison of the ultrasonographic diagnosis with the histopathological findings demonstrated excellent agreement between the two diagnostic methods. Of the 14 histopathologically confirmed malignant lesions, 13 were correctly identified as malignant by transvaginal ultrasonography combined with Color Doppler, whereas one malignant lesion was incorrectly classified as benign (false negative). Among the 118 benign lesions, 113 were correctly identified as benign, while five lesions were incorrectly classified as malignant (false positives). These findings indicate a high level of diagnostic concordance between ultrasonographic assessment and the reference standard (Table 5).

Table 5. Comparison of ultrasound diagnosis with histopathology

Ultrasound diagnosis	Histopathology malignant	Histopathology benign
Malignant	13	5
Benign	1	113
Total	14	118

The diagnostic performance of transvaginal ultrasonography combined with Color Doppler demonstrated excellent accuracy for differentiating benign from malignant adnexal masses during pregnancy. The imaging modality achieved a sensitivity of 92.9% and a specificity of 95.8%, indicating a high ability to correctly identify both malignant and benign lesions. Furthermore, the positive predictive value (PPV) was 72.2%, whereas the negative predictive value (NPV) reached 99.1%, reflecting an excellent ability to exclude malignancy when the ultrasonographic findings suggested a benign lesion. The high positive likelihood ratio (22.1) and low negative likelihood ratio (0.07) further supported the strong discriminatory performance of the combined imaging approach. Overall, the diagnostic accuracy was 95.5%, demonstrating the reliability of transvaginal ultrasonography with Color Doppler for the preoperative evaluation of adnexal masses during pregnancy (Table 6).

Table 6. Diagnostic performance of TVUS with Color Doppler

Diagnostic parameter	Value (95% CI)
Sensitivity	92.9% (66.1–99.8)
Specificity	95.8% (90.3–98.6)
Positive Predictive Value	72.2%
Negative Predictive Value	99.1%
Overall Accuracy	95.5%
Positive Likelihood Ratio	22.1
Negative Likelihood Ratio	0.07
Diagnostic Odds Ratio	316.9

Receiver operating characteristic (ROC) curve analysis further confirmed the excellent diagnostic performance of the combined imaging modality. The combined use of transvaginal ultrasonography and Color Doppler produced an area under the curve (AUC) of 0.964 (95% CI: 0.927–0.998; $p < 0.001$), indicating outstanding discriminatory ability for differentiating malignant from benign adnexal masses. In comparison, grayscale ultrasonography alone yielded an AUC of 0.884, whereas Color Doppler alone demonstrated an AUC of 0.911. These findings indicate that integrating grayscale ultrasonography with Color Doppler provided superior diagnostic performance compared with either modality used independently (Table 7).

Table 7. ROC analysis

Variable	AUC	95% CI	p-value
Combined TVUS + Color Doppler	0.964	0.927–0.998	<0.001

Gray-scale ultrasound alone	0.884	0.801–0.956	<0.001
Color Doppler alone	0.911	0.842–0.973	<0.001

Multivariable binary logistic regression analysis identified several independent sonographic predictors of malignant adnexal masses after adjustment for potential confounding variables. The presence of central vascularity emerged as one of the strongest predictors of malignancy **(**AOR = 10.56; 95% CI: 2.71–41.08; p < 0.001**),** followed by a Resistance Index (RI) below 0.45 **(**AOR = 12.34; 95% CI: 3.11–48.93; p < 0.001**).** Similarly, solid components**,** papillary projections**,** and lesion size greater than 8 cm were independently associated with a significantly increased likelihood of malignancy. These findings highlight the importance of integrating both morphological and Doppler vascular features to improve the preoperative risk stratification of adnexal masses during pregnancy (Table 8).

Table 8. Multivariable logistic regression analysis

Variable	Adjusted OR	95% CI	p-value
Solid component	8.94	2.35–34.02	0.001
Papillary projection	6.88	1.84–25.71	0.004
Central vascularity	10.56	2.71–41.08	<0.001
RI <0.45	12.34	3.11–48.93	<0.001
Lesion size >8 cm	3.42	1.08–10.82	0.036

DISCUSSION

The present study evaluated the diagnostic accuracy of transvaginal ultrasonography (TVUS) combined with Color Doppler in differentiating benign from malignant adnexal masses during pregnancy, using histopathological examination as the reference standard. The findings demonstrated excellent diagnostic performance, with high sensitivity (92.9%), specificity (95.8%), and an overall diagnostic accuracy of 95.5%. These findings suggested that the combination of grayscale ultrasonography with Color Doppler assessment substantially enhanced the preoperative characterization of adnexal masses during pregnancy and could facilitate timely clinical decision-making while minimizing unnecessary surgical interventions.

Benign adnexal masses accounted for approximately 89% of all lesions, whereas malignant tumors represented nearly 11% of the cases. This distribution was consistent with previous studies demonstrating that most adnexal masses diagnosed during pregnancy were benign functional cysts or benign ovarian neoplasms, whereas malignant lesions remained relatively uncommon (9,10). Functional ovarian cysts and corpus luteum cysts constituted the largest proportion of benign lesions in the present study, reflecting the physiological hormonal changes associated with pregnancy that contributed to transient ovarian cyst formation (11,12). Similar observations were reported by Hakoun et al., who noted that functional cysts represented the predominant ovarian lesions encountered during early pregnancy and frequently resolved spontaneously without surgical intervention (4).

Morphological assessment using grayscale transvaginal ultrasonography demonstrated that lesion size, papillary projections, thick septations, solid components, bilateral involvement, and ascites were significantly associated with malignant pathology (13). These findings were consistent with the established sonographic criteria proposed by the International Ovarian Tumor Analysis (IOTA) group and the Ovarian-Adnexal Reporting and Data System (O-RADS), which identified irregular solid components, multilocular-solid morphology, papillary excrescences, and ascites as major predictors of ovarian malignancy (14,15). Similar observations were reported by Timmerman et al. and Van Calster et al., who demonstrated that morphological evaluation remained the cornerstone of preoperative ovarian tumor characterization (16–18).

The addition of Color Doppler markedly improved diagnostic confidence by identifying significant differences in vascular characteristics between benign and malignant lesions (19). Malignant tumors demonstrated increased central vascularity together with significantly lower resistance index (RI) and pulsatility index (PI) values compared with benign lesions (20). These findings supported the biological concept that malignant ovarian tumors underwent neoangiogenesis, producing abnormal vascular networks characterized by low vascular resistance and increased blood flow (21). Previous investigations similarly reported that central vascularity and low-resistance Doppler waveforms were among the strongest imaging predictors of ovarian malignancy, particularly when interpreted alongside grayscale morphological features (22).

The clinical implications of these findings were particularly important in pregnancy, where balancing maternal benefit against fetal safety remained a major consideration. Accurate preoperative differentiation between benign and malignant adnexal masses could reduce unnecessary surgical procedures for lesions likely to resolve spontaneously while ensuring the timely referral of women with suspected malignancy to specialized gynecologic oncology services. Because magnetic resonance imaging (MRI) was not always readily available in many low- and middle-income countries, transvaginal ultrasonography with Color Doppler offered an accessible, affordable, and radiation-free imaging modality suitable for routine obstetric practice (4). Improved diagnostic confidence could also facilitate multidisciplinary planning regarding the timing and extent of surgical intervention during pregnancy.

Despite these encouraging findings, several limitations should be considered when interpreting the results. The study was conducted at a single tertiary care center, which might have limited the generalizability of the findings to other healthcare settings. The relatively small number of malignant cases reflected the low incidence of ovarian malignancy during pregnancy and might have influenced the precision of the diagnostic performance estimates. In addition, ultrasound interpretation was inherently operator-dependent, and interobserver variability was not formally assessed. Finally, although histopathology served as the reference standard for surgically managed patients, women who were managed conservatively were followed clinically rather than undergoing immediate tissue diagnosis, thereby introducing the potential for verification bias.

Nevertheless, the present study possessed several notable strengths. The prospective diagnostic accuracy design minimized recall bias and enabled standardized data collection. Histopathological confirmation served as the gold standard for diagnostic verification, thereby enhancing the validity of the findings. The inclusion of both grayscale ultrasonography and Color Doppler parameters provided a comprehensive assessment of the morphological and vascular characteristics of adnexal masses. Future multicenter studies involving larger sample sizes and more diverse populations are warranted to validate these findings across different healthcare settings. Comparative studies evaluating transvaginal ultrasonography with emerging diagnostic models such as the IOTA ADNEX model, O-RADS, and machine learning-based risk prediction tools may further improve diagnostic accuracy. Longitudinal investigations assessing maternal and neonatal outcomes following different management strategies would also provide valuable evidence for optimizing clinical guidelines. In resource-limited settings, future research should additionally evaluate the cost-effectiveness and implementation of standardized ultrasound-based diagnostic protocols.

Routine incorporation of Color Doppler into transvaginal ultrasonographic evaluation should be considered for pregnant women with persistent or sonographically complex adnexal masses to improve preoperative risk stratification. Standardized reporting systems such as the IOTA Simple Rules and O-RADS should be integrated into routine clinical practice to improve diagnostic consistency. Larger multicenter prospective studies are recommended to validate these findings and establish pregnancy-specific diagnostic thresholds for Doppler indices. Future research should also evaluate the integration of artificial intelligence-assisted image analysis and investigate the long-term maternal and fetal outcomes associated with different management strategies for adnexal masses diagnosed during pregnancy.

CONCLUSION

The findings of the present study suggested that transvaginal ultrasonography combined with Color Doppler provided excellent diagnostic performance in differentiating benign from malignant adnexal masses during pregnancy. The integration of morphological assessment with Doppler evaluation of tumor vascularity improved diagnostic confidence and accurately identified sonographic features associated with malignancy. As a safe, non-invasive, widely available, and cost-effective imaging modality, TVUS combined with Color Doppler had the potential to facilitate early diagnosis, optimize individualized patient management, reduce unnecessary surgical interventions, and improve maternal and fetal outcomes. Further large-scale multicenter prospective studies were recommended to validate these findings and support the development of standardized, evidence-based clinical guidelines for the evaluation and management of adnexal masses during pregnancy.

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