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Diagnostic Accuracy of Gray-Scale Ultrasonography and Color Doppler Ultrasonography in Differentiating Benign from Malignant Ovarian Masses

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ABSTRACT

Background: Ovarian cancer is one of the deadliest gynecological cancers in the world, and late diagnosis of the disease is a major factor in poor survival rates. The correct and timely diagnosis of benign and malignant ovarian masses is crucial to direct clinical management. This study aimed to assess the diagnostic value of gray-scale ultrasonography and color Doppler ultrasonography in differentiating benign from malignant ovarian masses. **Methods & Materials:** This cross-sectional study was conducted in the Department of Radiology and Imaging, Sylhet MAG Osmani Medical College Hospital, Sylhet, Bangladesh, from July 2018 to June 2019. 32 patients with sonographically identified ovarian masses were recruited according to the inclusion and exclusion criteria. All patients were evaluated by gray-scale and color Doppler ultrasonography and then the resected tissue was examined histopathologically. Sonographic parameters such as mass morphology, vascularity, resistance index (RI), and pulsatility index (PI) were documented and correlated with the histopathology. Data were entered and analyzed on SPSS version 26. **Results:** The benign and malignant ovarian masses on histopathology were found in 19 (59.4%) and 13 (40.6%) of the 32 participants, respectively. The sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy of gray-scale ultrasonography were 76.9%, 78.9%, 71.4%, 83.3%, and 78.1%, respectively. The sensitivity, specificity, PPV, NPV, and accuracy of color Doppler ultrasonography were 92.3%, 89.5%, 85.7%, 94.4%, and 90.6%, respectively. Malignant masses were more likely to be bilateral, show high central vascularity, and low RI (<0.50) and PI (<1.00). **Conclusion:** Color Doppler ultrasonography is much more accurate than gray-scale ultrasonography alone in distinguishing between benign and malignant ovarian masses. Both modalities are useful in the preoperative evaluation of ovarian masses, and their combination is reliable, non-invasive, and cost-effective.

Keywords: *Ovarian masses; Gray-scale ultrasonography; Color Doppler ultrasonography; Diagnostic accuracy; Histopathology*

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INTRODUCTION

Ovarian masses are among the most difficult to diagnose in gynecologic practice, from completely benign functional cysts to highly malignant diseases. Ovarian cancer is one of the deadliest of all gynecological cancers, largely due to the lack of an effective early detection system and the vague symptoms at early stages of the disease [1]. Ovarian cancer is the third or fourth most common type of cancer in women, and most of the cases are diagnosed at an advanced stage, with a five-year survival rate of less than 30% [2]. In developing countries like Bangladesh, the problem is further complicated by the lack of advanced diagnostic facilities and the late presentation of the disease, which makes it very important to differentiate the benign and malignant masses preoperatively [3]. The clinical history and physical examination alone are not enough to make a good distinction between benign and malignant adnexal masses. Tumor markers, including CA-125, have shown poor specificity, especially in premenopausal women, where other conditions like endometriosis, fibroids, and pelvic inflammatory disease can lead to high levels [4]. Computed tomography (CT) and magnetic resonance imaging (MRI) provide high-resolution images, but are not available in many resource-limited areas, are expensive, and expose patients to radiation (CT) [5]. Therefore, ultrasonography, especially transvaginal and transabdominal, has become the most important imaging technique for the diagnosis of ovarian masses due to its non-invasiveness, real-time imaging, availability, and cost-effectiveness [6]. Gray-scale ultrasonography (USG) offers detailed morphological information about ovarian masses, such as size, echogenicity, wall characteristics, internal septations, papillary projections, and ascites [7]. These features have been used to develop several morphological scoring systems to distinguish ovarian masses as benign or malignant. Gray-scale USG, however, has its own limitations in discriminating solid or complex masses; the echogenicity of the tissue may not be sufficient to reliably distinguish between malignancy and non-malignancy [8]. Color Doppler ultrasonography (CDU) has significantly improved the diagnostic armamentarium by allowing evaluation of tumor vascularity and hemodynamic flow patterns. Malignant ovarian tumors typically show low impedance blood flow, which is seen as a decreased resistance index (RI <0.50) and pulsatility index (PI <1.00) on Doppler analysis [9]. These vascular properties are useful in distinguishing malignant masses from benign lesions, which usually have high-resistance peripheral flow or lack vascularity [10]. Although significant progress has been made in imaging technology, there is a lack of strong data from South Asian environments to assess the combined diagnostic accuracy of gray-scale and color Doppler ultrasonography in comparison to histopathology. Sensitivities and specificities have been reported to be variable in neighboring countries and other low-middle income countries, highlighting the need for locally validated evidence [11]. The aim of this study was therefore to assess the diagnostic value of gray-scale ultrasonography and color Doppler ultrasonography in differentiating benign from malignant ovarian masses.

METHODS & MATERIALS

This cross-sectional study was conducted in the Department of Radiology and Imaging, Sylhet MAG Osmani Medical College Hospital, Bangladesh, from July 2018 to June 2019. The patients were consecutively sampled, and a total of 32 female patients with ultrasonographically detected ovarian masses were enrolled. Patients were

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included if they had a confirmed ovarian mass on initial ultrasound and were scheduled for surgical intervention, and had a histopathologic examination as the reference standard. Patients with a history of ovarian surgery, those who had undergone hormonal therapy or chemotherapy in the last six months, pregnant women, and patients with poor ultrasound windows due to obesity or bowel gas interference were excluded from the study. The study variables were age, parity, menopausal status, clinical symptoms, gray-scale ultrasonographic characteristics (laterality, type of mass, presence of septation, thick septation, papillary projections, solid components, irregular wall, and ascites), and color Doppler characteristics (vascularity pattern, location of vascularity, resistance index [RI], pulsatility index [PI], and Doppler impression). Before surgery, a trained radiologist performed standardized gray-scale and color Doppler ultrasonographic examination on each enrolled patient. The vascular flow pattern was assessed by color Doppler, and the RI <0.50 and PI <1.00 were set as thresholds for malignancy. The final histopathological diagnosis after surgical resection was taken as the gold standard for comparison. Data were entered and analyzed in SPSS version 26. Frequencies and percentages were used to present descriptive statistics. Diagnostic accuracy parameters such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy were computed. Categorical comparisons were made using the chi-square test, and a p-value < 0.05 was considered statistically significant.

RESULTS

The sociodemographic distribution of the study participants is represented in *Table I*. The benign group (n=19) was mainly composed of younger women, most of whom were aged 30-39 years (31.6%), and no cases were found under 30 years of age in the malignant group. The age distribution of the malignant cases was skewed, with 30.8% in the 40-49 age group, 23.1% in the 60 years and over age group, and 30.8% in the 50-59 age group. The proportion of those living in urban areas was almost similar for both groups (57.9% benign and 53.8% malignant). Both benign and malignant groups had a high prevalence of multiparity (73.7% and 92.3%, respectively). The majority of benign cases were premenopausal (84.2%), while the majority of malignant cases were postmenopausal (61.5%).

Table I
Sociodemographic profile by histopathological diagnosis of the study population (*n*=32).

Variable	Category	Benign (n=19), n (%)	Malignant (n=13), n (%)
Age group	<30 years	5 (26.3%)	0 (0.0%)
	30-39 years	6 (31.6%)	2 (15.4%)
	40-49 years	5 (26.3%)	4 (30.8%)
	50-59 years	2 (10.5%)	4 (30.8%)
	≥60 years	1 (5.3%)	3 (23.1%)
Residence	Urban	11 (57.9%)	7 (53.8%)
	Rural	8 (42.1%)	6 (46.2%)
Parity	Nulliparous	5 (26.3%)	1 (7.7%)
	Multiparous	14 (73.7%)	12 (92.3%)
Menopausal status	Premenopausal	16 (84.2%)	5 (38.5%)
	Postmenopausal	3 (15.8%)	8 (61.5%)

The clinical characteristics observed in both benign and malignant groups are summarized in *Table II*. The most common symptom in both groups was lower abdominal pain (78.9% benign; 69.2% malignant). Abdominal distension was considerably more prevalent in malignant cases (76.9%) than in benign cases (36.8%). Likewise, gastrointestinal symptoms (46.2% vs. 10.5%), weight loss or anorexia (46.2% vs. 5.3%), urinary symptoms (30.8% vs. 10.5%), and palpable abdominal mass (61.5% vs. 26.3%) were more common in the malignant group. Menstrual irregularity was more common in benign cases (42.1% vs. 23.1%), and a family history of ovarian or breast malignancy was reported in 15.4% of malignant and 5.3% of benign cases.

Table II
Clinical presentation by histopathological diagnosis of the study population (*n*=32).

Variable	Benign (n=19), n (%)	Malignant (n=13), n (%)
Lower abdominal pain	15 (78.9%)	9 (69.2%)
Abdominal distension	7 (36.8%)	10 (76.9%)
Menstrual irregularity	8 (42.1%)	3 (23.1%)
Gastrointestinal symptoms	2 (10.5%)	6 (46.2%)
Urinary symptoms	2 (10.5%)	4 (30.8%)
Weight loss/anorexia	1 (5.3%)	6 (46.2%)
Palpable abdominal mass	5 (26.3%)	8 (61.5%)
Family history of ovarian/breast malignancy	1 (5.3%)	2 (15.4%)

There were multiple responses.

The gray-scale ultrasonographic characteristics of ovarian masses are shown in *Table III*. Benign masses were more likely to be unilateral (89.5%) while malignant masses were more likely to be bilateral (53.8%). Benign masses were mainly cystic (52.6%), whereas solid-cystic (61.5%) and predominantly solid (30.8%) configurations were more common in malignant masses. The malignant masses had significantly higher frequencies of septation (76.9 %), thick septation (53.8%), papillary projections (53.8%), solid components (84.6%), irregular wall (69.2%), and ascites (46.2%) than the benign masses, which had significantly lower frequencies of these features.

Table III
Gray-scale ultrasonographic findings by histopathological diagnosis (*n*=32).

Variable	Category	Benign (n=19), n (%)	Malignant (n=13), n (%)
Laterality	Unilateral	17 (89.5%)	6 (46.2%)
	Bilateral	2 (10.5%)	7 (53.8%)
Nature of mass	Cystic	10 (52.6%)	1 (7.7%)
	Solid-cystic	8 (42.1%)	8 (61.5%)
	Predominantly solid	1 (5.3%)	4 (30.8%)
Septation	Present	8 (42.1%)	10 (76.9%)
Thick septation	Present	3 (15.8%)	7 (53.8%)
Papillary projection	Present	2 (10.5%)	7 (53.8%)
Solid component	Present	4 (21.1%)	11 (84.6%)
Irregular wall	Present	3 (15.8%)	9 (69.2%)
Ascites	Present	1 (5.3%)	6 (46.2%)

Table IV shows the colour Doppler ultrasonographic features of ovarian masses. Marked vascularity was seen in the majority of malignant masses (61.5%), while absent or minimal vascularity was seen in the majority of benign masses (47.4%). Peripheral vascularity was more frequent in benign (68.4%) than in malignant cases (15.4%), and central or septal vascularity was more frequent in malignant cases. A resistance index (RI) of less than 0.50 was recorded in 84.6% of malignant and only 15.8% of benign masses. Likewise, a pulsatility index (PI) of less than 1.00 was seen in 84.6% of malignant cases compared to 42.1% of benign cases.

Table IV
Color Doppler ultrasonographic findings by histopathological diagnosis (*n*=32).

Variable	Category	Benign (n=19), n (%)	Malignant (n=13), n (%)
Vascularity	Absent/minimal	9 (47.4%)	1 (7.7%)
	Moderate	8 (42.1%)	4 (30.8%)
	Marked	2 (10.5%)	8 (61.5%)
Site of vascularity	Peripheral	13 (68.4%)	2 (15.4%)
	Central/septal	6 (31.6%)	11 (84.6%)
Resistance index, RI	≥0.50	16 (84.2%)	2 (15.4%)
	<0.50	3 (15.8%)	11 (84.6%)
Pulsatility index, PI	≥1.00	11 (57.9%)	2 (15.4%)
	<1.00	8 (42.1%)	11 (84.6%)

The distribution of histopathological diagnoses is shown in *Table V*. In the 19 benign cases, serous cystadenoma was the most common diagnosis (36.8%), followed by mucinous cystadenoma (26.3%), dermoid cyst (21.1%), and endometrioma (15.8%). Of the 13 malignant cases, serous cystadenocarcinoma accounted for 46.2%, mucinous cystadenocarcinoma for 23.1%, endometrioid carcinoma for 15.4%, and borderline epithelial tumour for 15.4%.

Table V
Histopathological diagnosis of ovarian masses (*n*=32).

Histopathological diagnosis	Category	Benign, n (%)	Malignant, n (%)
Benign lesions	Serous cystadenoma	7 (36.8%)	-
	Mucinous cystadenoma	5 (26.3%)	-
	Dermoid cyst	4 (21.1%)	-
	Endometrioma	3 (15.8%)	-
Malignant lesions	Serous cystadenocarcinoma	-	6 (46.2%)
	Mucinous cystadenocarcinoma	-	3 (23.1%)
	Endometrioid carcinoma	-	2 (15.4%)
	Borderline epithelial tumour	-	2 (15.4%)

The diagnostic accuracy parameters of gray-scale and color Doppler ultrasonography were compared in *Table VI*. The sensitivity, specificity, PPV, NPV, and overall diagnostic accuracy of gray-scale ultrasonography were 76.9%, 78.9%, 71.4%, 83.3%, and 78.1%, respectively. The color Doppler ultrasonography showed excellent performance in all parameters, with a sensitivity of 92.3%, specificity of 89.5%, PPV of 85.7%, NPV of 94.4%, and overall accuracy of 90.6%.

Table VI
Diagnostic accuracy of gray-scale and color Doppler ultrasonography.

Modality	Sensitivity	Specificity	PPV	NPV	Accuracy
Gray-scale ultrasonography	10/13 (76.9%)	15/19 (78.9%)	10/14 (71.4%)	15/18 (83.3%)	25/32 (78.1%)
Color Doppler ultrasonography	12/13 (92.3%)	17/19 (89.5%)	12/14 (85.7%)	17/18 (94.4%)	29/32 (90.6%)

A cross-tabulation of ultrasonographic impressions with histopathological diagnoses for both modalities is presented in *Table VII*. Of the cases diagnosed as benign by gray-scale USG, 83.3% were confirmed as benign and 16.7% as malignant by histopathology, while 71.4% of those diagnosed as malignant by gray-scale USG were truly malignant and 28.6% were benign, with a statistically significant association (p=0.002). The concordance of Color Doppler USG was better, with 94.4% of benign impressions being confirmed as benign and 85.7% of malignant impressions being confirmed as malignant by histopathology.

Table VII
Comparison of ultrasonographic diagnosis with histopathology.

Diagnostic modality	USG impression	Benign, n (%)	Malignant, n (%)	p-value
Gray-scale USG	Benign	15 (83.3%)	3 (16.7%)	0.002
	Malignant	4 (28.6%)	10 (71.4%)	
Color Doppler USG	Benign	17 (94.4%)	1 (5.6%)	<0.001
	Malignant	2 (14.3%)	12 (85.7%)	

DISCUSSION

This study demonstrated that color Doppler ultrasonography (accuracy 90.6%) significantly outperforms gray-scale ultrasonography (accuracy 78.1%). The predominance of benign masses in younger and premenopausal women, and malignant masses in older and postmenopausal women, is consistent with Kaijser et al. [12]. Post menopause has long been known to be a major risk factor for ovarian malignancy, with the reduction in ovulatory cycles linked to a greater susceptibility to epithelial proliferation [13]. The increased number of palpable abdominal masses, abdominal distention, and constitutional symptoms (weight loss) in the malignant group in our study is similar to a study by Doubeni et al., and may represent the more advanced clinical stage at which ovarian cancers are often diagnosed [14]. As far as gray-scale ultrasonographic characteristics are concerned, malignant masses were more likely to be bilateral, solid or solid-cystic, with thick septations, papillary projections, irregular walls, and ascites than benign masses in our study. These morphological characteristics have been well described by Timmerman et al. as markers of malignancy and are included in the standardized scoring systems like the IOTA (International Ovarian Tumor Analysis) simple rules [15]. The sensitivity and specificity of gray-scale USG in our study (76.9% and 78.9%, respectively) are similar to those reported by Moore et al. in a similar study design (75% and 80%, respectively) [16]. Timmerman et al. reported sensitivities >90% with the IOTA classification, which could be attributed to a multicenter study design and the use of experienced sonologists, which might explain higher performance than in single-center studies [15]. The advantage of colour Doppler ultrasonography in our study is mainly due to its ability to identify the pathological neo-angiogenesis phenomenon found in malignant tumours. Tumor-associated vessels are thin-walled, irregular, and have no smooth muscle in their wall, which leads to low vascular resistance (RI <0.50 and PI <1.00) [17]. In our study, the RI of malignant masses was <0.50 in 84.6% and benign masses in 15.8%. The results are similar to those of Stefan et al., who found an RI < 0.50 to have a sensitivity of 87% and specificity of 83% for malignancy [18]. Similarly, Sokalska et al. showed that the overall diagnostic accuracy was significantly higher when morphological and Doppler criteria were used together, which is supported by the results of this study [19]. The sensitivity and specificity of 92.3% and 89.5%, respectively, achieved in this study are comparable to those reported by Desai et al., which were 91.6% and 88.2%, respectively [20]. The NPV of 94.4% for colour Doppler USG in our study is also clinically significant as a benign Doppler impression reliably excludes malignancy, which may be useful in the conservative management of younger patients. The statistically significant correlation between Doppler impression and histopathological diagnosis (p<0.001) further confirms the clinical value of colour Doppler as a complementary modality. Epithelial tumors were the most common in both benign (serous and mucinous cystadenomas) and malignant (serous cystadenocarcinoma) groups histopathologically. This distribution is similar to the worldwide distribution of ovarian tumor types, in which epithelial tumors make up about 90% of ovarian malignancies [21]. The predominance of serous subtypes in our malignant group is also similar to the report by Holcakova et al. [22]. Notably, borderline epithelial tumors were seen in 15.4% of malignant cases, reflecting the difficulty in diagnosis by ultrasonography in this intermediate category, which can be atypical on gray-scale and Doppler imaging. The findings of this study confirm the complementary use of gray-scale and color Doppler ultrasonography in the evaluation of ovarian mass before surgery. Combined use of both modalities allows for a more thorough morphological and hemodynamic evaluation, which increases diagnostic certainty and may decrease the number of unnecessary surgical interventions for benign masses and ensure prompt referral and management of malignant masses [23]. The ultrasonographic approach is a practical and reproducible method for ovarian mass characterization in resource-limited healthcare settings where MRI and PET-CT are not routinely available.

LIMITATIONS

A small sample size of 32 participants from a single tertiary care center may restrict the generalizability of the results to other populations. Further, the lack of serum tumor marker (CA-125) data and the exclusion of advanced imaging modalities (MRI/CT) for cross-comparison are limitations of the extent of the diagnostic evaluation.

CONCLUSION

The results of this study demonstrated that gray-scale and color Doppler ultrasonography are useful non-invasive methods for distinguishing benign from malignant ovarian masses preoperatively. The overall diagnostic accuracy of color Doppler ultrasonography is 90.6%, which is higher than the diagnostic accuracy of gray-scale ultrasonography alone (78.1%). Bilaterality, solid components, thick septations, papillary projections, irregular walls, and ascites are key USG features that suggest malignancy, while color Doppler is reliable for malignancy when the central vascularity is marked, and the flow indices are low (RI <0.50 and PI <1.00). In this study population, patient-level risk factors for ovarian malignancy include postmenopausal status and older age. Gray-scale and color Doppler ultrasonography is a cost-effective, readily available, and repeatable method for preoperatively characterizing ovarian masses, especially in resource-limited areas, and should be used as the standard of care before surgery.

RECOMMENDATIONS

Larger, multicenter studies with the addition of CA-125 levels, 3D ultrasonography, and new artificial intelligence-assisted sonographic analysis would further support the evidence base for optimal preoperative ovarian mass characterization. Longitudinal studies of postoperative results associated

with preoperative ultrasonographic results are also warranted.

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CONFLICT OF INTEREST
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