Original Article

Diffusion-Weighted Imaging-Based Differentiating between Benign and Malignant Ovarian Lesions

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Abstract

Background: Ovarian cancer is a common female malignancy frequently identified at advanced stages. Diffusion-weighted imaging (DWI) provides valuable information on structural traits of tissue and is used as an imaging biomarker in OST cancer prognosis. Post-processing of three-dimensional apparent diffusion coefficient (ADC) maps has proven useful in evaluating variable tumors, although its position in ovarian cancer prognosis is until now not well defined. Consequently, our foremost objective was to assess the sensitivity and efficiency of DWI (T1 and T2) and ADC maps in malignant and benign ovarian lesions prognosis.

Matherials and Methods: A total of 58 patients with undetermined ovarian masses in ultrasound were referred to MRI for more accurate diagnosis. The signals of DWI (qualitative) and ADC values (quantitative DWI) of the lesion components were analyzed separately. Student's *t*-test and receiver operating characteristic (ROC) curves were used to determine the ability of DWI and ADC in the discrimination between malignant and benign ovarian masses.

Results: Of the 58 masses, 33 have been benign, and 25 have been malignant. There was a decrease correlation between signal thing on T2W and ADC values in malignant as compared to benign masses. The DWI and T1 + GAD values in malignant tumors have been substantially higher than the ones in benign masses (P value < 0.0001). Additionally, our consequences suggest that a T1 cutoff value ($1 \times 10^{-} \geq$ mm²/s) would possibly the quality factor to help discriminate between benign and malignant lesions.

Conclusions: The mixture of DWI imaging with T1 + GAD values can beautify the diagnostic overall performance in discrimination among benign and malignant ovarian masses by increasing specificity.

Keywords: Diagnostic imaging, diffusion magnetic resonance imaging, ovarian cancer

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Introduction

Ovarian tumors are often referred to as "silent killers" because they tend to be diagnosed at later stages.[1] Early diagnosis and timely intervention play a significant role in improving results, reducing complications and mortality in patients with ovarian masses. Until recently, CT scans were the primary preoperative method used to detect ovarian masses, particularly to predict respectability. However, new technologies in the imaging field such as DWI/MRI and PET/CT, coupled with advancements in ultrasound technology, have made preoperative diagnosis more accurate.[2]

Given that adnexal masses present with a wide range of symptoms, diagnosis is often difficult, especially when imaging findings are suboptimal or inconclusive.[3] This problem

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confirms the importance of access to early and accurate diagnosis strategies, which should replace screening methods with low sensitivity and specificity. The more important issue is the implementation of the treatment plan and follow-up based on the diagnosis results.[4] Prevalent guidelines recommend reliable methods, risk-reduction strategies, and shared intention-making. According to research, the main benefit of MRI is the soft tissue resolution, which allows to determine the functional features of soft tissue.[5,6]

The special diffusion property is the reason for the apparent contrast between tumor tissue (diffusion limited) and normal tissue (non-diffusion limited). Due to this, diffusion-weighted imaging (DWI) has been used in this research, which is a type of MR imaging based on measuring the random Brownian motion of water molecules inside a tissue voxel. This method provides the possibility of differentiating healthy tissues from abnormal and malignant tissues with a high accuracy of 90%.[7,8]

Apparent diffusion coefficient (ADC) is another effective factor in creating diffusion contrast, which shows the water molecules enclosed in the tissue as a lower signal and actually confirms the findings of DW images.[9] Tissue diffusion is quantified with the aid of calculating ADC values. Diffusion-weighted images are explicated collectively with the ADC maps and morphological images.

To our knowledge, few studies have been performed on the simultaneous examination of DWI (T1 and T2) and ADC with the aim of quantitative (DWI) and qualitative (ADC) assessment of ovarian masses to achieve an accurate and non-invasive imaging technique. Accordingly, the purpose of this study was to appraised the main criteria of DWI for differentiation of malignant and benign adnexal masses in order to achieve a useful and non-invasive imaging method. Evaluation the sensitivity and diagnostic value of DWI, using the T2 mapping sequence to quantify the signal of the acquired images, signal intensity analysis, and ROC curve evaluation are the special goals of this project. Considering the importance of the issue, it has not been evaluated so far.

Materials and Methods

Patients and study setting

This retrospective cross-sectional study was conducted after the approval by our university Ethics Committee, with informed consent obtained from all participants. From March 2020 to March 2022, 58 consecutive women who were referred to Taleghani Hospital (Abadan, Iran) MRI center for the differential diagnosis of adnexal lesions were included. The selection was contingent on clinical history and transabdominal or transvaginal ultrasound detections. All patients signed written consent before MRI examination. Standardized MRI protocols, including DWI, ADC, T2, and T1 + GAD sequences, were used, and pathology results from the biopsied lesions were extracted for evaluation. To appraise the diagnostic value of MRI in the diagnosis of tumor malignancy, the pathology result to the title of gold standard was chosen.

Inclusion criteria: Age >18 years, standardized MRI scan with DWI, ADC, T2, and T1 sequences.

Exclusion criteria: Age <18 years, non-standard MRI scan, prior hysterectomy, acute symptoms, or lack of histopathological findings.

MRI was conducted using a 1.5 Tesla MR scanner (GE Healthcare, USA). A 32-channel phased array coil was situated over the lower abdomen for all patients.

If no contraindications were present, patients were administered 20 mg of N-butylbromide (Buscopan, Boehringer Ingelheim, Germany) intravenously to reduce intestinal peristalsis.

The standard MRI protocol sequences included axial and sagittal scans of the lower abdomen. These sequences spanned from the pubic symphysis to the iliac crests. Parameters for T1-weighted imaging were as follows: TR = 459.95 ms, slice thickness = 4 mm, TE = 8 ms, slice gap = 0.5 mm, scan duration = 1.18 min, FOV = 45 cm, matrix = 256 × 25.

T2W-TSE images (turbo spin echo) were achieved in the sagittal, coronal, and axial planes with TR = 3500 ms, TE = 90 ms, slice gap = 1.5 mm, slice thickness = 4 mm, and a scan duration of 1.17 min. Diffusion MRI was performed using a single-shot echo-planar imaging sequence (TR/TE: 9000-18000/30-60), slice thickness = 3–5 mm, slice gap = 1.5 mm, FOV = 45 cm, and matrix = 128 × 128, at a *P* value of 800s/mm².

A total of 0.2 mL of gadolinium chelate (per kg of body weight) become given by way of a power injector at a velocity of 2 mL/s, then 20 mL of normal saline was given to flush the tube. Consecutive images have been received at 2.4 s intervals beginning 10 s before bolus injection, for a total of 320 s.

To remove the artifacts caused by the high signals of subcutaneous fat, all the sequences are placed in front with saturation bands. All results were correlated to final post-operative histopathological data and correlated to the imaging findings of each sequence.

Statistical analysis

SPSS v. 20 was became used for statistical evaluation. Data had been described using range, mean ± SD, and frequencies (quantity of cases), with percentages where appropriate. Mann-Whitney and Kruskal-Wallis tests were performed for quantitative information comparisons, while Fisher's exact test and Chi-square tests were used for qualitative data comparisons. Sensitivity, specificity, and standard accuracy had been evaluated with ROC curve evaluation to determine the cutoff values of semi-quantitative parameters. Statistical significance became set at $P < 0.05$.

Results

In this study, 58 females aged between 28 and 71 were evaluated. The lesions were classified based on histopathology

results: 33 cases (53.4%) were benign, and 25 cases (46.6%) were malignant. The type of mass investigated presented in [Table 1].

The mean age of participants was not significantly different between those who came down with benign ovarian lesions and those with malignant ovarian lesions. (P = 0/094) [Table 2].

There was no significant age difference between contributors with benign or malignant ovarian tumors (P = 0.094). The MRI and DWI results were accurate in detecting malignancies, with lower signal intensity in T2W and ADC values for benign masses compared to malignant ones. The DWI and T1 + GAD values for malignant tumors were significantly higher than those for benign masses. (P < 0.0001) [Table 3].

The ROC curve changed into used to decide the cutoff values of the semi-quantitative parameters [Figure 1].

The area under ROC curve regarding the indicative power of T2-weighted signal intensity in distinguishing benign from malignant masses is equal to 0.679 [Table 4]. According to this analysis, the best cutoff point for deterining benign from malignant masses, which has the maximal sensitivity and specificity, was the cutoff point of 826/81 [Table 5].

The ROC curve identified the apical cutoff point for T2-weighted signals to distinguish between benign and malignant masses, with an area under the curve (AUC) of 0.679. Sensitivity and specificity for recognizing between benign and malignant masses using T2-weighted images were 45.2% and 100%, respectively, with an accuracy of 70.68%.

The diagnostic power of ADC had an AUC of 0.725, with a cutoff point that provided 54.8% sensitivity and 100% specificity [Figure 2 and Table 6].

As can be seen in the table above, the sensitivity and specificity of ADC in identifying benign from malignant masses were equal to 54.8% and 100%, respectively; the PPV and NPV have been identical to 100% and 65.9%. The total accuracy is equal to 75.86%, and the level of agreement was moderate (Kappa = 0.531, P < 0.001) [Table 7].

DWI had an AUC of 0.999, with 100% sensitivity and 96.8% specificity for detecting malignant from benign masses [Figure 3].

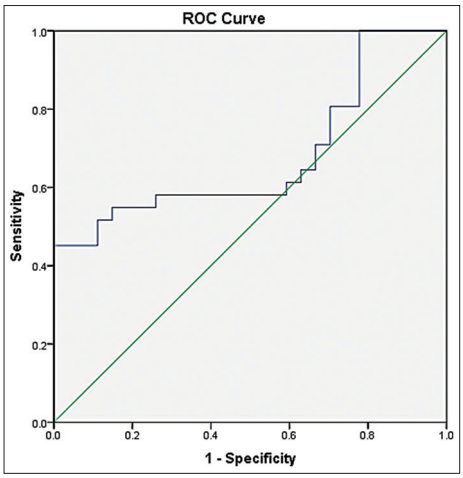

Figure 1: ROC curve regarding the diagnostic power of T2-WSI in distinguishing benign from the malignant mass

Table 1: Frequency distribution of tumor type in terms of histopathology in the study

Tumor	Type of tumor	Distribution
Fallopian tube tumor	Benign	2
Ovarian cysts	Benign	1
Simple cyst	Benign	1
Dermoid cyst	Benign	8
Endimethrioma	Benign	10
Functional cyst	Benign	1
Hemorrhagic cyst	Benign	2
Hemorrhagic cyst	Benign	1
Krukenberg tumor	Benign	7
Mucinous	Malignant	7
Carcinoma	Malignant	6
Ovarian serous tumors	Malignant	5
Ovarian yolk sac tumor	Malignant	1
Popliteal cysts	Malignant	6
Simple cysts	Malignan	6

Table 2: Mean and standard deviation (SD) of age in patients diagnosed with benign and malignant ovarian masses

Variable	Lesion	Mean	Number	SD	*P*
Age (year)	Benign	39.26	31	9.121	0/094
	Malignant	46.04	27	19.891	

Table 3: Mean and standard deviation of T1 + GAD in patients with benign and malignant tumor

Variable	Tumor	Num	Mean	SD	*P*
T1 + GAD	Benign	33	24.441	9.544	≤0.0001
	Malignant	25	154.16	27.924	
T2W	Benign	33	678.56	42.367	≤0.0001
	Malignant	25	432.87	36.239	
ADC	Benign	33	995/39	157.06	≤0.0001
	Malignant	25	115.69	53.5	
DWI	Benign	33	184.71	132.6	≤0.0001
	Malignant	25	548.03	80.02	

Table 4: The area under the ROC curve regarding the diagnostic power of T2-WSI in distinguishing benign from malignant masses

Confident limits 95%		Significance	Standard error	Under cure area
Upper line	Lower line			
0.820	0.537	0.02	0.072	0.679

Table 5: The diagnostic of T2-weighted signal intensity in distinguishing benign from malignant masses at the cutting point 826/81

Kapa		Accuracy	Negative probability	Positive probability	Negative value	Positive value	Property	Sensitivity	False neg	True neg	False pos	True pos
Sig	Coefficient											
<0/001	0.434	70.68%	0.548	-	61/8%	100%	100%	45/2%	17	27	0	14

Table 6: Area under the rocking curve regarding the diagnostic power of ADC in distinguishing benign from malignant masses

Confident limits 95%		Significance	Standard error	Under cure area
Upper line	Lower line			
0.858	0.593	0.003	0.068	0.725

As can be seen in the table above, the sensitivity and specificity of DWI in identifying malignant from benign masses were equal to 100% and 96.8%, respectively. The PPV and NPV were equal to 96.4% and 100%. The total accuracy was equal to 98.27%, and the level of agreement was excellent (Kappa = 0.965, $P < 0.001$) [Tables 8 and 9].

The analysis of T1 + GAD had an AUC of 1.0, indicating 100% sensitivity and specificity [Figure 4].

As can be seen in the table above, the sensitivity and specificity of T1 + GAD in distinguishing malignant from benign masses were equal to 100%. The PPV and NPV were equal to 100%. The total accuracy was equal to 100%, and the level of agreement was excellent (Kappa = 1, $P < 0.001$) [Tables 10 and 11].

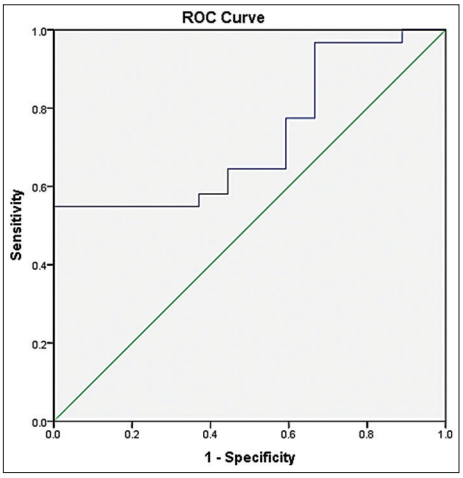

Figure 2: ROC curve regarding the diagnostic power of ADC in distinguishing benign from malignant masses

Discussion

Ovarian cancer is recognized as one of the most lethal malignancies in women. The delay in diagnosis, which typically results in the disease reaching an advanced stage, significantly limits the available treatment options.[10] This emphasizes the importance of early detection of ovarian masses to enable more effective treatment planning, predicting treatment results and fertility preservation for young women.[11] Our study focused on the effectiveness of DWI in combination with ADC mapping to enhance the sensitivity and specificity of MRI for detecting ovarian malignancies.[12,13] To our knowledge, few studies have been performed on the simultaneous examination of DWI (T1 and T2) and ADC with the aim of quantitative (DWI) and qualitative (ADC) assessment of ovarian masses to achieve an accurate and non-invasive imaging technique. The results indicated that DWI-based diagnosis improves both the sensitivity and specificity of MRI, reaching levels between 93.3% and 100%, with a comparable specificity of 85% to 96.8%. Our findings are consistent with the previous studies showing that ADC values tend to be lower in malignant tumors than in benign ones. This supports the role of ADC in discriminating malignant from benign lesions. Additionally, the integration of T1 + GAD images with ADC provided valuable insights, significantly improving the diagnostic capability.

It was further observed that the presence of extremely signal intensity in T1 + GAD weighted imaging, along with lower ADC values, was particularly useful in differentiating malignant ovarian lesions. The previous studies, including those conducted by Ali *et al*.[14] and Tantawy *et al*.,[15] have corroborated our findings, noting the value of DWI and ADC in improving diagnostic performance. Other researchers, such as Michielsen *et al*.,[16] have demonstrated the ability of MRI with DWI to accurately detect ovarian masses with a sensitivity of 91% and specificity ranging from 89% to 100%. The findings of mentioned study are similar to our study, and it was also found that the diagnostic accuracy, sensitivity, and specificity of DWI in diagnosing ovarian malignant masses are very accurate. Michielsen *et al*.[16] established that DWI/MRI was accurate in revealing ovarian masses with a sensitivity of 91%, specificity of 91%, PPV of 89%, NPV of 93%, and accuracy of 91%. Notably, Abd-ElMageed *et al*.[17] highlighted the promise of DWI in accurately characterizing gynecological tumors. Their findings suggested that DWI had a sensitivity of 95% and could successfully differentiate between benign and malignant lesions. Our results align with these studies, as our study showed 100% sensitivity for identifying adnexal masses, although specificity was relatively lower.

On the other hand, some researchers concluded that DWI is not a specific diagnostic method, and its capability is only in differentiating ovarian mixed masses.[18,19]

These collective findings suggest that while DWI and ADC mapping are powerful diagnostic tools for ovarian cancer detection, more research is required to refine these methods

Table 7: The diagnostic of ADC in distinguishing benign from malignant masses at the cutting point 335/84

Kapa		Accuracy	Negative probability	Positive probability	Negative value	Positive value	Property	Sensitivity	False neg	True neg	False pos	True pos
Sig	Coefficient											
<0/001	0.531	75.86%	0.452	–	65/9%	100%	100%	54/8%	14	27	0	17

Table 8: The area under the rocking curve regarding the diagnostic power of DWI in distinguishing malignant from benign masses

Confident limits 95%		Significance	Standard error	Under cure area
Upper line	Lower line			
1.000	0.995	0.000	0.002	0.999

Table 9: The diagnostic of DWI in distinguishing benign from malignant masses at the cutting point 414/23

Kapa		Accuracy	Negative probability	Positive probability	Negative value	Positive value	Property	Sensitivity	False neg	True neg	False pos	True pos
Sig	Coefficient											
<0/001	0.965	98.27%	0	31.25	100%	96.4%	96.8%	100%	0	30	1	27

Table 10: The area under the rocking curve regarding the investigation of the diagnostic power of T1 + GAD in distinguishing malignant from benign masses

Confident limits 95%		Significance	Standard error	Under cure area
Upper line	Lower line			
1.000	1.000	0.000	0.000	1.000

Table 11: The diagnostic of T1 + GAD in distinguishing benign from malignant masses at the cutting point 75/74

Kapa		Accuracy	Negative probability	Positive probability	Negative value	Positive value	Property	Sensitivity	False neg	True neg	False pos	True pos
Sig	Coefficient											
<0/001	1	100%	0	–	100%	100%	100%	100%	0	31	0	27

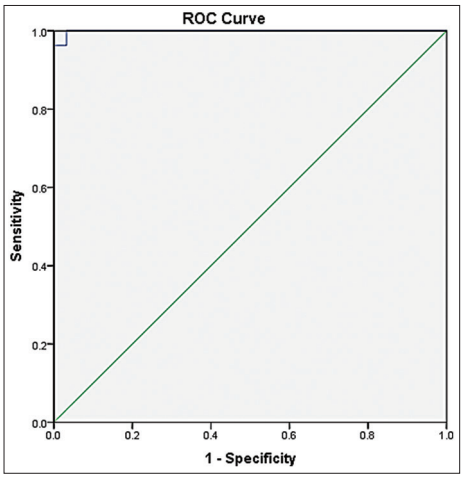

Figure 3: ROC curve regarding the diagnostic power of DWI in distinguishing malignant from benign masses

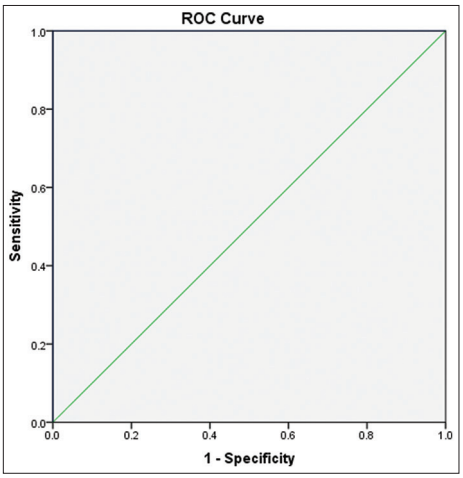

Figure 4: ROC curve regarding the diagnostic power of T1 + GAD in distinguishing malignant from benign masses

further. Differences in device settings, imaging protocols, and patient-specific factors might impact ADC values, suggesting a need for a more standardized approach across clinical settings.

In conclusion, this study underscores the value of DWI, combined with functional imaging techniques, in improving ovarian cancer detection, but

further research is needed to fully optimize its diagnostic capabilities.

In the contemporary take a look at, the ADC values had been significantly higher inside the benign organization than inside the malignant institution. There have been reports of significantly different ADC values between benign and malignant ovarian tumors.[20,21] In evaluation, different researchers endorse that ADC value has no position in differentiating benign from malignant ovarian tumors.[22-24] It seems that the contradictory results obtained regarding the ability to detect ADC for benign from malignant masses[25] can be due to the difference in ADC value even in the same patient in keeping with the device, imaging parameters used, patient group, and tumor type and differentiation.

Conclusions

Our study demonstrates that incorporating DWI, T1 + GAD imaging, and ADC value measurements improves the diagnostic accuracy of MRI in differentiating among benign and malignant ovarian masses. The identified T1 cutoff value of $1 \times 10^{-} \geq mm^2/s$ is a strong predictor for distinguishing between these types of lesions. Early and accurate diagnosis of ovarian masses is crucial for enhancing patient effects through timely intervention and better treatment planning.

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Conflicts of interest

All authors certify that this manuscript has neither been published in whole nor in part nor is it being considered for publication elsewhere. The authors have no conflict of interest to declare.

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