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The role of diffusion weighted MRI and contrast enhanced MR imaging in evaluation of ovarian tumors

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Abstract: Background: Studies reported the role of diffusion weighted MRI and contrast enhanced MR imaging in differentiating benign from malignant ovarian tumors. **Aim of the Work**: Evaluate the role of DW-MRI and CE-MRI in diagnosis of ovarian tumors. **Patients and Methods:** This study conducted on 40 patients complaining from ovarian pathology related symptoms. Patients with renal failure, artificial valves, cardiac pacemaker, clips or any ferromagnetic implants were excluded **Results:** A total number of 40 patients with48 ovarian masses were detected,22 of them were diagnosed as malignant,22 as benign,2 as borderline. All solid malignant tumors, borderline tumors and solid components of complex lesions showed diffusion restriction as well. Most benign lesions did not display diffusion restriction in DWI. The best cut off value of ADC to discriminate between benign & malignant lesionswas≤0.9, with sensitivity of 88.9% specificity of 81.8% positive predictive value of 80%, negative predictive value of 90%. The contrast enhanced MRI is useful in characterization of types of the tumors. **Conclusion:** The study revealed that adding the diffusion weighted imaging and ADC to MRI study are of highly statistically significant value.

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Key words: Magnetic resonance imaging MRI, diffusion weighted DW, Contrast enhanced CE, apparent diffusion coefficient adc.

1. Introduction

Ovarian masses are a common finding in daily clinical practice and may be incidentally detected or identified in symptomatic patients. Characterization of an ovarian lesion represents a diagnostic challenge; it is of great importance in the preoperative setting in order to plan adequate therapeutic procedures **(1).**

Ovarian cancer causes more deaths than any other cancer of female reproductive system; despite accounting for only 3% of all cancers in women. When ovarian cancer is found in its early stages, treatment is most effective. It is of great importance to characterize an adnexal mass as accurately as possible to guide appropriate management, so treatment options become more specific. This is particularly true for young women who should be offered conservative surgery for fertility preservation **(2).**

In the evaluation of patients with adnexal lesions the MRI has become an important tool and solve the problem of adnexa; most malignant and benign lesions can be diagnosed by MRI with high confidence and high accuracy than other modalities **(3).**

Aim of the work

Study the role of diffusion weighted MRI and contrast enhanced MR imaging in evaluation of ovarian tumors.

2. Subjects and methods

The present work is study. It was conducted on forty female patients, aged 12–76years old, This study included 40 female patients during period from April 2016 till September 2019. The patients were complained from symptoms suggestive of ovarian pathology and referred from the Gynecology department to the Radiology department of radiodiagnosis of Cairo university (Women's imaging unit) based on preliminary ultrasound examination used for cases selection. This study was carried out in the premium out in the permission of ethics committee, Faculty of Medicine for girls, Al-Azhar university.

MR imaging technique:

Patients were instructed to fast for 3 hours and void urine 2 hours prior examination.

Intravenous administration of 10 mg of an antispasmodic drug (Visceralgine) was given immediately before MR imaging to reduce bowel peristalsis. MR imaging was performed on Philips medical system using a 1.5-T magnet. All patients were imaged in the supine position with the aid of pelvic phased-array coil. High Resolution Isotropic Volume Examination) images were obtained immediately after manually injected-gadolinium at a dose of 0.1 mmol/kg of body weight (maximum, 20 mL), this was followed by injection of 20 mL of normal saline flushing the tube. In some cases post contrast T1is done without fat sat.

The planes were taken for most of patients were: Axial T1, axial T1 SPAIR, axial T2, sagittal T2, coronal T2, axial T1 post contrast, sagittal T1post contrast, coronal T2 post contrast, axial DWI and post processing ADC map.

Statistical analysis:

Recorded data were analyzed using the statistical package for social sciences, version 20.0 (SPSS Inc., Chicago, Illinois, USA). Quantitative data were expressed as mean± standard deviation (SD). Qualitative data were expressed as frequency and percentage.

The confidence interval was set to 95% and the margin of error accepted was set to 5%. So, the p-value was considered significant as the following:

Probability (P-value)

– P-value <0.05 was considered significant.

– P-value <0.001 was considered as highly significant.

– P-value >0.05 was considered insignificant.

3. Results:

The present study was conducted on 40 female patients, their ages ranged from 12-76 years and mean age of 38.38±16.16.

In our study 48 ovarian masses were detected in 40 studied patients. The 48 masses were classified into 22(45.8%) as malignant ovarian masses and 24(50%) as benign ovarian masses and 2(4.2%) as borderline masses according to MRI and DWI/ADC value and histopathological correlation as.

Table (1): MRI nature of 48 ovarian masses detected in our study.

MRI nature	NO.	%
Mixed (cystic and solid)	27	56.3%
Cystic	13	27.0%
Multilocular cyst	9	69.2%
Unilocular cyst	4	30.8%
Solid	8	16.7%
Total	48	100.0%

The MRI nature of ovarian masses detected in our study. 27 (56.3%) masses were of Mixed nature,13 (27%) masses were of cystic nature which further subdivided into 9 (69.2%) masses are multilocular cystic and 4(30.8%) masses are unilocular cysts and 8 (16.7%) are solid masses.

Table (2): Comparison between malignant and benign 48 ovarian masses according to MRI nature.

MRI nature	Malignant		Borderline		Benign		Chi-square test	
	No.	%	No.	%	No.	%	x2	p-value
Mixed (Cystic and Solid)	18	81.8 %	2	100.0%	7	29.2%	12.158	<0.001**
Multilocular Cyst	1	4.6%	0	0.0%	8	33.3%	4.897	0.027*
Unilocular Cyst	0	0.0%	0	0.0%	4	16.7%	2.463	0.117

This table showed that 18 (81.8%) of malignant masses were of mixed nature and about 3(13.6%) of solid nature and 1(4.6%) of multilocular nature. There were about 7 (29.2%) of benign cases of mixed nature and about 8(33.3%) of multilocular cyst nature and about 5(20.8%) of solid nature and about 4(16.7%) of unilocular cyst nature. There were statistically significant difference between malignant and benign masses according to mixed and multilocular cyst MRI nature.

Table (3): Comparison between malignant and benign masses detected in detected in 48 ovarian masses in our study according to contrast enhancement.

Contrast Enhancement	Malignant		Borderline		Benign		Chi-square test	
	No.	%	No.	%	No.	%	x2	p-value
Enhanced	22	100.0%	2	100.0%	23	95.8%	0.480	0.489
Not Enhanced	0	0.0%	0	0.0%	1	4.2%		
Total	22	100.0%	2	100.0%	24	100.0%		

This table shows,22 (100.0%) of malignant masses showed contrast enhancement and 23(95.8%) of benign masses also enhanced. only one benign case which showed. no enhancement and that was statistically insignificant. 2(100.0%) of borderline masses also showed contrast enhancement.

Table (4): Comparison between malignant benign and borderline ovarian masses according to DWI.

DWI	Malignant		Benign		Borderline		Chi-square test	
	No.	%	No.	%	No.	%	x2	p-value
High Signal (Restricted)	22	100.0%	11	45.8%	2	100.0%	12.143	<0.001**
Low Signal (Facilitated)	0	0.0%	13	54.2 %	0	0.0%		
Total	22	100.0%	24	100.0%	2	100.0%		

This table showed that About 22 (100.0%) of malignant masses showed high signal in DWI while 11(45.8%) of benign masses showed high signal in DWI and the remaining 13 (54.2%) benign masses had low signal in DWI and 2(100.0%) of borderline masses showed high signal in DWI and that was highly statistically significant difference (P<0.001).

Table (5): Comparison between malignant, benign and borderline 48 ovarian masses according to ADC Map.

ADC Map	Malignant		Benign		Borderline		Chi-square test	
	No.	%	No.	%	No.	%	x2	p-value
High Signal	0	0.0%	11	45.8%	0	0.0%	11.583	<0.001**
Low Signal	22	100.0%	13	54.2%	2	100.0%		
Total	22	100.0%	24	100.0%	2	100.0%		

This table shows, 22 (100.0%) of malignant masses had low signal in ADC map while 13(54.2%) of benign masses had low signal in ADC map and that was highly statistically significant difference between malignant and benign masses (P value <0.001). The remaining 11(45.8%) benign masses had high signal intensity in ADC map and 2(100.0%) borderline masses had low signal in ADC map.

Table (6): showed Comparison between malignant and benign and borderline ovarian masses according to ADC of cystic component.

ADC of Cystic Component	Malignant *(n=16)*	Benign *(n=22)*	Borderline *(n=2)*	ANOVA	p-value
Mean±SD	2.44±0.43	2.06±0.54	2.70±0.42	3.851	0.041*
Range	1.8–3.5	1.2–2.8	2.4–3		

Our results showed that statistically significant difference between mean ADC value of cystic component of malignant, benign and borderline cases (P value 0.041*), as the mean ADC value of malignant masses was 2.44±0.43 compared to benign masses which was 2.06±0.54 and the mean of borderline masses was 2.70±0.42.

Table (7): Comparison between malignant, benign and borderline according to ADC value x (10^-3 mm^2/s) of solid component.

ADC value x (10^-3 mm^2/s)	Malignant *(n=15)*	Benign *(n=11)*	Borderline *(n=2)*	ANOVA	p-value
Mean±SD	0.76±0.11	1.12±0.38	1.30±0.14	8.368	0.002*
Range	0.50-0.90	0.60-1.80	1.2-1.4		

Our results showed that statistically significant difference between mean ADC value of solid component of malignant and benign and borderline cases (P value 0.002*), as the mean ADC value of malignant masses was 0.76±0.11 compared to benign masses which was 1.12±0.38 and the mean of borderline masses was 1.30±0.14.

Table (8): Comparison between malignant and benign and borderline ovarian masses detected in our study according to ADC value x (10^-3 mm^2/s).

ADC value x (10^-3 mm^2/s)	Malignant *(n=22)*	Borderline (n=2)	Benign *(n=24)*	t-test	p-value
Mean±SD	0.77±0.11	1.30±0.14	1.58±0.71	10.574	<0.001**
Range	0.5–0.9	1.2–1.4	0.6–2.8		

There was highly statistically significant decrease in mean ADC value of malignant masses (0.77±0.11) as compared to the mean ADC value of benign masses (1.58±0.71) (P value <0.001) (Table). The ADC range of malignant masses was 0.5-0.9 while in benign masses the ADC range was 0.6–2.8. The mean ADC value of borderline masses was 1.30±0.14 and the ADC ranged 1.2–1.4.

Table (9): Receiver-operating characteristic (ROC) curve parameters for prediction of malignant masses using the ADC value x (10^-3 mm^2/s).

Cut-off	Sen.	Spe.	PPV	NPV	AUC
≤0.9	88.9%	81.8%	80%	90%	0.838

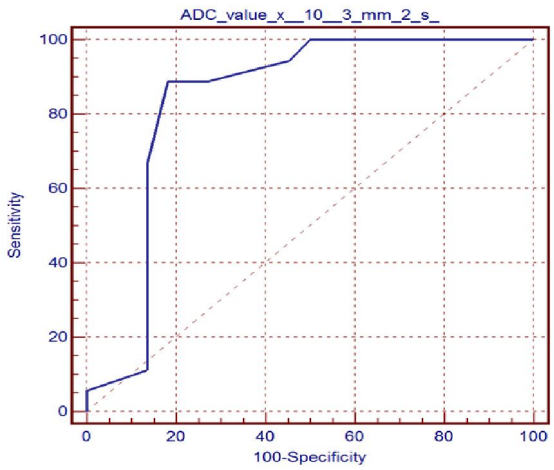

Fig. (1): (ROC) curve was used to define the best cut off value of ADC value x (10^-3 mm^2/s) which was ≤0.9, with sensitivity of 88.9% specificity of 81.8% positive predictive value of 80%, negative predictive value of 90% with diagnostic AUC of 0.838.

Table (10): showed other MRI features associated with ovarian masses.

	No.	%
Ascites	16	40.0%
Enlarged lymph nodes	5	12.5%
Omental deposits	3	7.5%
Ovarian torsion	3	7.5%
Local invasion	1	2.5%

This table shows that the enlarged lymph nodes detected in (12.5%) of cases, Omental deposits detected in (7.5%) of cases, Ascites detected in (40.0%) of cases, Ovarian torsion detected in (7.5%) of cases and Local invasion detected in (2.5%) of cases.

4. Discussion:

Ovarian cancer causes more deaths than any other cancer of female reproductive system; despite accounting for only 3% of all cancers in women. When ovarian cancer is found in its early stages, treatment is most effective. It is of great importance to characterize an adnexal mass as accurately as possible to guide appropriate management, so treatment options become more specific. This is particularly true for young women who should be offered conservative surgery for fertility preservation **(Maarof R et al., 2018) (2).**

In the evaluation of patients with adnexal lesions the MRI has become an important tool and solve the problem of adnexa; most malignant and benign lesions can be diagnosed by MRI with high confidence and high accuracy than other modalities **(Amir K,2017) (3).**

MRI is well known to provide accurate information about hemorrhage, fat, and collagen. It is able to identify different types of tissue contained in pelvic masses, distinguishing benign from malignant ovarian tumors **(El Wakil et al.,2019) (1).**

In our study, we investigated the diagnostic value of contrast enhanced MRI and diffusion MRI in the diagnosis and characterization of ovarian tumors.

Gadolinium is usually reserved for improved delineation of papillary projections, nodules, and thick septations in ovarian cancers. Conventional and contrast material– enhanced MR imaging are used to evaluate morphologic features, including lesion complexity, signal intensity, and enhancement of solid areas **(Prasad A et al.,2018) (4).**

Diffusion-weighted imaging (DWI) is a potentially useful technique in the assessment of adnexal masses **(Foti et al., 2016) (5).**

This study was conducted on 40 female patients with age ranged from 12–76 years and mean age of 38.38±16.16. By analyzing the age distribution among patients with ovarian tumors, we found that the ages of the patients diagnosed as having benign ovarian tumors ranged from 14–70 years, most of them were seen in age less than 50years this is in agreement with Prasad et al.,2018 who found that Most of the benign lesions were seen in age less than 50 years. The patient diagnosed as having malignant tumors their range of age were 12–76 years with the majority of cases were below 50 years and this is disagree with **Prasad et al.,2018(4)** who conducted a study on 60 female patient with ovarian tumors and found that majority of the malignant lesions were seen in age more than 50 years.

As regard the site of the tumor our study found that 8 cases were bilateral (two of them were

metastatic and two were serous carcinoma 1 fibrothecoma,1dysgerminoma,1serous cystadenoma and 1was endometroid carcinoma) and this is in agreement with **Mukuda et al.,2018(5)** who found that most bilateral ovarian tumors on MR imaging were defined as serous carcinoma, mature teratoma or metastasis. The rest of cases (32) are unilateral.

Considering the MRI components of the tumors, our findings are in line with those of other studies **(Foti et al., 2016) (6)** and **(Halanker et al., 2017) (7)** that used conventional imaging and showed that unilocular cysts are benign tumors, cystic and solid tumors were mostly malignant, multilocular cysts were mostly benign, solid lesions some of them are benign and some were malignant.

The fat containing tumors are diagnosed by suppressed its high signal in STAIR, our study contains 7cases of mature cystic teratoma and 1case immature teratoma.

In this study, all the malignant and borderline lesions as well as 45.8 % of the benign lesions showed high signal in diffusion with low signal in ADC map "diffusion restriction". The benign lesions that showed restricted diffusion were (7mature cystic teratoma,2fibrothecoma,1thecoma,1mucinouscystadenoma). These findings were consistent with **Agostinho et al.,2019(8).** who found that malignant tumors present restricted diffusion, whereas benign tumors do not. Nevertheless, some lesions that constitute exceptions to that rule: teratomas, and some benign sexcord-stromal tumors.

In our study the mean ADC value of cystic component shows statistically significant increase mean of malignant compared to benign tumors. It is 2.44±0.43 in malignant and 2.06±0.54 in benign tumors with p value <0.05. Similarly Tantawy et al.,2018 who conducted study on 30 patients with complex cystic ovarian masses found that ADC values of cystic component in malignant masses were significantly higher than those in benign masses (p < 0.05). Mean adc value of benign tumors is 2.047, mean adc for malignant is 2.44 ± 0.314. These findings were in disagreement with **El‐Wekilaet.,2019(1)** the ADC value of the cystic component did not differ significantly between benign and malignant masses (P = 0.195) as it was for benign tumors 1.603 × 10‒3 ± 0.49 × 10‒3mm2/s, and 1.223 × 10‒3 ± 0.53 × 10‒3 mm2/s for malignant tumors which was considered statistically insignificant.

Our results showed that statistically significant difference between mean ADC value of solid component of malignant and benign tumors (P value 0.002*), as the mean ADC value of malignant masses was 0.76±0.11 compared to benign masses which was 1.12±0.38. This is in agreement with **El Wekila et al., 2019(1)** who conducted a study on 30 female patients and found that the mean ADC value of the solid component can differ significantly between benign and malignant masses (P < 0.001) as it was 1.176 × 10-3 ± 0.15 × 10-3 mm 2/s for benign tumors, and 0.747 × 10-3 ± 0.12 × 10-3 mm 2/s for malignant tumors which were also considered statistically significant.

In our study the mean ADC of malignant tumors was 0.77±0.11, mean ADC of borderline tumors was 1.30±0.14 and mean ADC of benign tumors was 1.58±0.71. lower ADC values associated with the malignant group were found to be statistically significant (p-value <0.05) was ≤0.9 may be an optimal cutoff value for differentiating benign and malignant ovarian tumors with sensitivity of 88.9% specificity of 81.8% positive predictive value of 80%, negative predictive value of 90% with diagnostic AUC of 0.838. These findings were in consistent **with Othman et al.,2017(9)** who conducted a study on included 26 female patients with indeterminate complex and solid ovarian masses and found the mean ADC values for malignant lesions was (0.9 X 10–3±0.1SDmm2/s), while that for benign lesions was (1.5 X 10–3±0.4SDmm2/s), the lower ADC values associated with the malignant group were found to be statistically significant (p-value <0.05) with 0.9 X 10–3mm2/s may be an optimal cutoff value for differentiating benign and malignant ovarian tumors with sensitivity 81.25%, specificity 100%, PPV 100%, NPV 76.9% and accuracy 90.7%. And these findings were in disagreement with **Metwally et al.,2017 (10)** who found that the mean ADC of benign tumors (1.22±0.20×10-3) and the mean ADC of malignat tumors is (0.82±0.07×10-3), the best cut off value of ADC which was 0.91, with sensitivity of 94.4% specificity of 91.7% positive predictive value of 94.4 %, negative predictive value of 91.7%. And also in disagreement with **El Wekila et., al 2019(1)** the mean ADC value of the solid component can differ significantly between benign and malignant masses (P < 0.001) as it was n1.176 × 10‒3 ± 0.15 × 10‒3mm2/s for benign tumors and 0.747 × 10‒3 ± 0.12 × 10‒3 mm2/s for malignant tumors which was also considered statistically significant, the optimal cutoff 1.16 × 10‒3 mm2/s which may be for differentiating between benign and malignant tumors So the ADC value can be used as a considerable value in the differentiation.

According to pattern of contrast enhancement our study find that the mucinous cystadenoma shows minimally enhanced wall and septations and most of serous cystadenomas shows minimally enhanced wall and septation and one case shows mildly enhanced wall and septations which are non significant enhancement and that is corresponding to **Prasad et al.,2018(4)** who find that the benign epithelial tumors

shows non significant thin wall and septal enhancement.

1case cystadenofibroma shows mild homogenous enhancement of the solid component similarly **Wasnik et al., 2013(11)** found that the solid portion of cystadenofibroma shows mild enhancement.

Mature cystic teratomas are variable in contrast enhancement 1cases shows no enhancement,4cases shows minimally enhanced wall, 1case shows mild heterogenous enhancement and 1case shows mild homogenous enhancement. Similarly Foti et al.,2016 found that the mature cystic teratomas has variable enhancement pattern.

1case immature teratoma shows moderate homogenous enhancement of the solid component.

1case fibrothecoma shows moderate homogenous enhancement, and two cases (one fibroma and another thecoma) shows avid homogenous enhancement. Similarly **Shingagare et al.,2012(12)** found that the enhancement of 58% of fibromas and fibrothecomas has homogenous enhancement and 48%have heterogenous enhancement on a study conducted on 35 women with pathologically proven ovarian fibromas or fibro the comas.

One case Brenner tumor shows mild homogenous enhancement. Similarly **Moon et al., 2000(13)** found that all solid component of Brenner tumors shows mild homogenous enhancement. In contrast **Park et al.,2014(14)** found that Brenner tumors demonstrate moderate enhancement after contrast material administration whereas fibrothecomas demonstrate minimal enhancement.

Three cases of serous cystadenocarcinoma two of them shows avid enhancement of the solid component similarly **Halanker et al.,2017(7)** found that serous cystadenocarcinoma has strongly enhancing solid component and one shows mildly enhanced wall and septations.

Three cases mucinous cystadenocarcinoma shows different pattern of enhancement (one case mild heterogenous enhancement of solid component, moderate heterogenous enhancement of solid component and the last one shows avid enhanced wall and septations. These findings were consistent with **Foti et al., 2016**(7) found that mucinous cystaden carcinomas shows enhancement of walls, septations, solid components and papillary projections.

One case endometroid carcinoma shows moderate homogenous enhancement of the solid component. This is in agreement with Li et al.,2015 who found that most endometroid ovarian tumors shows moderate enhancement.

One case dysgerminoma shows mildheterogenous enhancement That is in agreement with **Tsuboyama et al., 2018(15)** found that dysgerminomas are heterogenous in contrast enhanced MRI.

One case sertolileydig tumor shows mild homogenous enhancement in contrast **Caietal., 2013 (16)** found that all the solid components of sertolileydigtunors were intensely enhanced after administration of contrast medium.

Two cases borderline tumor (serous cystadenoma poorly differentiated, juvenile type granulosa cell tumor) show mild heterogenous enhancement of papillary projections and avid, homogenous enhancement respectively.

There are another two cases of malignantgranulosa cell tumors (juvenile and adult type) show avid heterogenous enhancement and mild homogenous enhancement of solid components respectively. These findings were in disagreement with **Zhang et al.,2018(17)** who made a study on 20 females with pathologically proved as granulosa cell tumor found that fourteen lesions (14/20) displayed mild enhancement and six showed moderate enhancement.

Two cases of metastatic ovarian tumors show mild enhancement of the septation and solid components. **Xu et al., 2015(28)** found that metastic ovarian tumors shows more moderate enhancement in solid portions than those of primary ovarian cancers which shows prominent enhancement.

The ancillary inclusion criteria may be important as they increase the diagnostic confidence of malignancy However, caution should be used regarding the presence of ascites. Ascites is not an unusual finding associated with benign lesions, mainly fibromas.

In our study 22.7% of patients with ascites had benign lesions. Similarly **Guerra et al., 2008 (19)** found that 32% of patients with ascites had benign lesions.

All patient with lymph nodes and peritonel implants found in our study had malignant tumors This is in agreement with **Prasad et al.,2018(4)**.

Conclusion:

Magnetic resonance (MR) imaging provides useful information for characterization of various ovarian tumors.

Contrast enhanced MRI allows better depiction of internal architecture and is useful in differentiating cystic from solid lesions and malignant from benign lesions.

DWI and ADC were of great importance in differentiating benign tumors from malignant, presence of peritoneal deposits and lymph node detection.

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