The Egyptian Journal of Radiology and Nuclear Medicine (2014) **45**, 975–985

Egyptian Society of Radiology and Nuclear Medicine

The Egyptian Journal of Radiology and Nuclear Medicine

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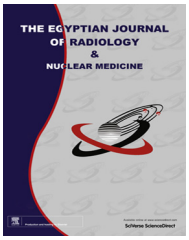

ORIGINAL ARTICLE

Dynamic contrast enhanced MRI in correlation with diffusion weighted (DWI) MR for characterization of ovarian masses

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Received 3 February 2014; accepted 2 April 2014
Available online 10 May 2014

KEYWORDS

Diffusion weighted;
Magnetic resonance imaging;
Dynamic;
Ovarian tumor

Abstract *Introduction:* Ovarian tumors; are the second most common gynecological tumor and are the fifth commonest tumor in women. It is desirable to preoperatively differentiate benign from malignant tumor to decide whether surgery is required, and which type of surgery is appropriate avoiding unnecessary surgery, adding dynamic contrast and diffusion weighted to conventional images can help in differentiation of benign ovarian tumor from malignant. DWI depends on the fact that water molecules can diffuse freely in low cellular environment, while tissue hyper cellularity causes its restriction. As a result, malignant ovarian tumors due to its hypercellular nature show restriction of diffusion, unlike most benign tumors. This study aims at reviewing and emphasizing the role of dynamic contrast enhanced MRI and diffusion-weighted MR in characterization of ovarian lesions.

Patients and methods: This study was performed on 30 patients referred to the radiology department from surgical department by ovarian masses. Pelvic MR with DWI was done for all patients, DCE-MR was done for 29 out of 30 patients. Twenty-five patients underwent surgery with pathologic correlation. Five patients were put under regular follow up US for 3 months.

Results: The sensitivity of MRI was 99.9% while that of DWI was 100%. The specificity was higher for DWI (75%) compared to conventional MRI (58.3%), as well as the accuracy which was 73.9% for MRI while that of DWI was 86.9%. The mean ADC values for malignant lesions were ($0.84 \times 10^{-3} \pm 0.1$ SD mm^2/s), while that for benign lesions were ($1.8 \times 10^{-3} \pm 0.5$ SD mm^2/s), with cut off 1.2×10^{-3} and p value = 0.005. Mature teratomas showed restricted diffusion with ADC values 0.8×10^{-3} mm^2/s (false positive), due to mixed cellularity of the teratoma.

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Peer review under responsibility of Egyptian Society of Radiology and Nuclear Medicine.

 http://dx.doi.org/10.1016/j.ejrnm.2014.04.002

Hemorrhagic cysts and endometriomas showed high signal not only on diffusion images but also on corresponding ADC map and ADC values 1.3–1.4 × 10^{-3} (T2 Shine-through). Sensitivity of MRI was 99.9% while that of DCE-MRI was 60%. The specificity was higher for DCE 91% compared to conventional MRI sequences 58.3%, as well as the accuracy which was 73.9% for MRI while that of DCE was 77% and so addition of DCE to the MRI is expected to increase the specificity and the accuracy of examination.

Conclusion: Combination of DWI and DCE to conventional MRI improves the specificity of MRI and thus increasing radiologist's confidence in image interpretation which will finally reflect on patients' outcome and prognosis.

1. Introduction

Functional imaging is becoming increasingly important in the evaluation of cancer patient in initial diagnosis and the assessment of response to therapy. Recent technical advances allow the use of dynamic and diffusion MR imaging in abdominal and pelvic applications (16).

DCE-MRI depends on the leakage of contrast agent from capillaries into the extravascular extracellular space, thus allowing quantitative analysis which reflects the blood flow and the vascular permeability (1).

DCE-MRI of ovarian tumors is recommended for accurate characterization of internal architecture, especially for delineation of necrosis, papillary projections, solid components, septations, and peritoneal implants (17).

Recent studies evaluated the use of DCE-MR imaging to further characterize adnexal masses. It provides information on tumor vascularity and perfusion. It also provides more post processing quantitative data (11).

DWI is a non-invasive modality that helps in discrimination between benign and malignant lesions, increases the contrast between lesions and surrounding tissues, and improves the detection and delineation of peritoneal implants at both initial staging and follow-up. Moreover, diffusion-weighted imaging provides quantitative information about tissue cellularity that may be used to distinguish viable tumors from treatment-related changes (7). When diffusion-weighted MR imaging is used in gynecologic applications, cancers have shown lower ADC (apparent diffusion coefficient) values. Increasing ADC values is noted in carcinomas responding to radiation therapy, so it can be used as a biomarker for treatment response, and in the evaluation of recurrence and multi focality (10).

This study aims at reviewing and emphasizing the role of dynamic contrast enhanced MRI and diffusion-weighted MR in characterization of ovarian lesions.

1.1. Patients and methods

This study was performed on 30 patients presented by ovarian masses, referred to the radiology department from surgical department based on U/S study as a prospective study. Pelvic MR with DWI was done for all patients, DCE-MR was done for 29 patients (one case was renal failure). Twenty-five patients underwent surgery with pathologic correlation. Five patients were put under regular follow up US for 3 months.

The study was conducted from November 2012 to June 2013 at the National Cancer Institute and Kasr El-Ainy hospital.

The patient's age ranged from 13 to 70 years.

Fourteen patients presented by vague pelvic pain, 6 were complaining of abdominal swelling, 6 accidentally discovered on regular post-operative follow up, 5 patients (after oophorectomy) for malignant ovarian tumor and one patient (after hemi colectomy) for cancer colon, and 4 patients were complaining of vaginal bleeding and infertility (see Cases 1–4).

All cases had been subjected to the full history taking with a special emphasis on: age, parity menstrual history, past history of gynecological troubles or operations, Pelvi-abdominal U/S TV/US and previous MRI.

1.2. MR imaging

MR imaging was performed on a 1.5-T MR imaging unit (Achieva, Philips medical system). All the patients were imaged in the supine position using pelvic phased-array Torso coil.

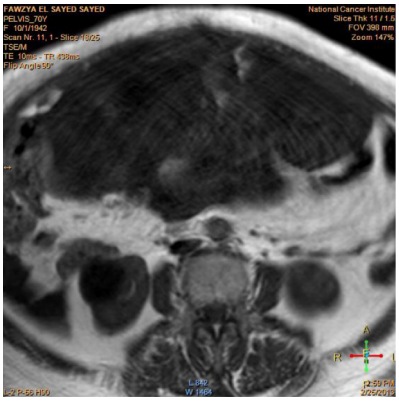
1.2.1. Patient preparation

Intravenous administration of an antispasmodic drug (10 mg of visceralgine) was given immediately before MR imaging to reduce bowel peristalsis.

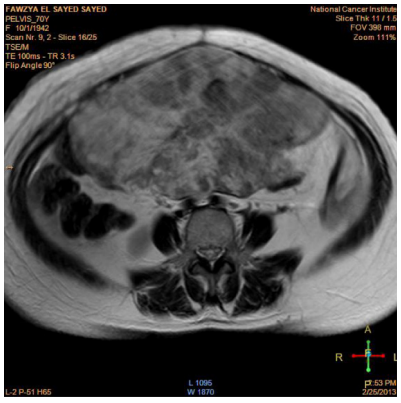
2. MR imaging protocol

- Non contrast.
- Axial T1-weighted (TR/TE, 500/10 ms).
- Axial T2-weighted (TR/TE, 3300/100 ms).
- Slice thickness, 6 mm. Gap, 1 mm. FOV, 32–42 cm. Matrix, 256 × 256.
- Sagittal T2-weighted and Coronal T2-weighted, Slice thickness, 8–10 mm. Gap, 1 mm. FOV, 40–50 cm. Matrix, 256 × 256.
- DW-MRI was acquired in the axial plane prior to administration of contrast medium by using a single shot echo-planar imaging sequence.
- With *b* values (0, 300, 600). TR/TE, 5000/70. Slice thickness, 6 mm. Gap, 1 mm. FOV, and 36 cm. Matrix, 128 × 128.

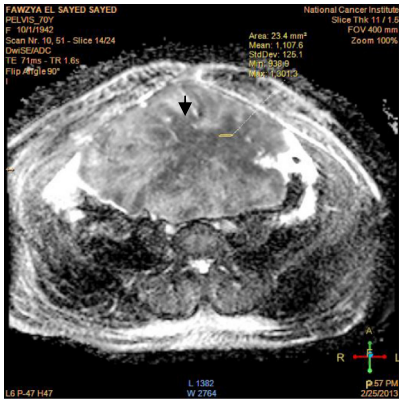
Dynamic contrast-enhanced MRI: post contrast T1 fat sat THRIVE (High Resolution Isotropic Volume Examination) images were obtained immediately after manually injected



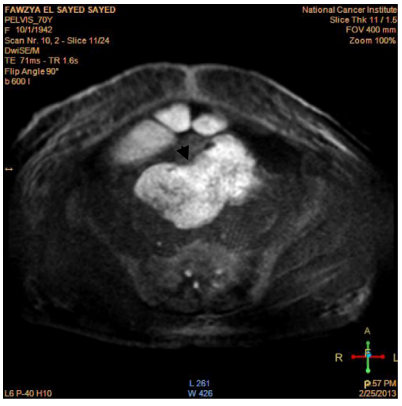
(a) axial spin echo T1 (TR/TE , 500/10 ms)



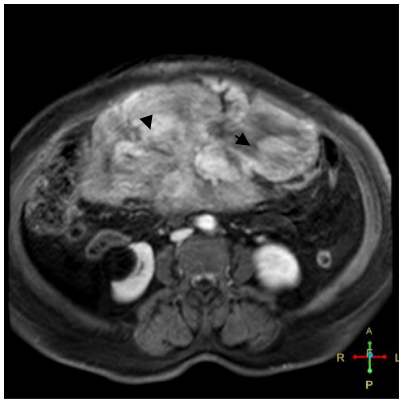
(b) axial T2(TR/TE , 3300/100 ms)



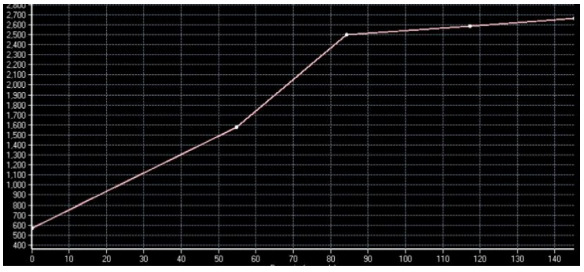
(c) DWI echo planar (TR/TE,5000/70)



(d) ADC



(e) T1 post contrast gradient echo(TR/TE,500/5)



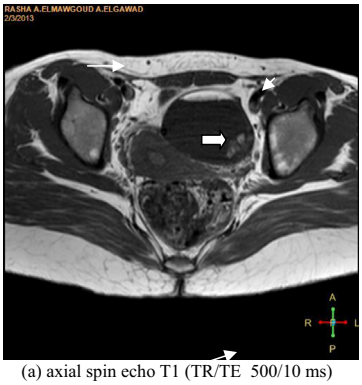
(f) dynamic curve

Case 1 70 year-old female patient complaining of abdominal swelling. US revealed a large left complex cystic adnexal lesion. Conventional MRI (a & b) showed left adnexal complex cystic mass with irregular thick wall and soft tissue component, eliciting heterogeneous low T1 and high T2 signal intensity denoting malignant looking left ovarian mass. DWI (c & d): the pelvic mass showed restricted diffusion in the form of high signal on DWI with corresponding low signal on ADC map (arrowed). ADC value was 0.9×10^{-3} mm^2/s. DWI suggested malignant nature. DCE-MRI (e & f): the lesion showed heterogeneous intense enhancement (arrowed) and the curve shows the following criteria: rising curve then plateau (type 11), with early peak at 70 s, and MRE 140%. MRI diagnosis (conventional, DWI and DCE-MRI) left complex malignant looking adnexal lesion. Pathology revealed malignant mucinous cystadenocarcinoma.

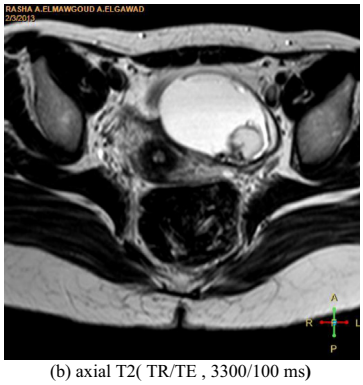
gadolinium at a dose of 0.1 mmol/kg of body weight (maximum, 20 mL), this was followed by injection of 20 mL of normal saline flushing the tube. Images were obtained sequentially at 0, 30, 60, 90 and 120 s. Finally, transverse, sagittal and coronal T1-weighted gradient-echo images were acquired.

2.1. MR imaging analysis

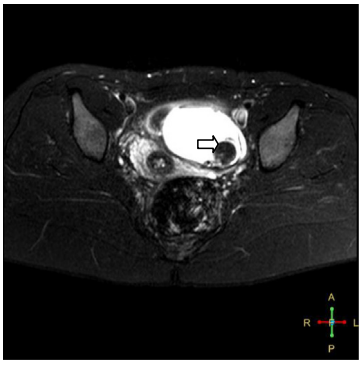
MR images were analyzed for the following: MR appearance of the tumor; either cystic, solid or mixed, involvement of one or both ovaries, size of the lesion, signal intensity of the



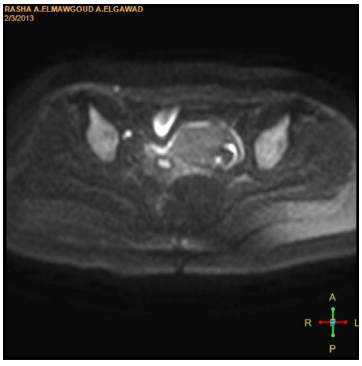
(a) axial spin echo T1 (TR/TE 500/10 ms)



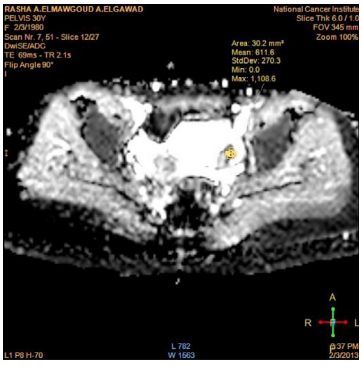
(b) axial T2(TR/TE , 3300/100 ms)



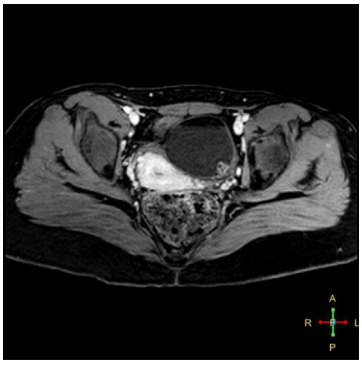
(c) Axial gradient echo T2fat suppression



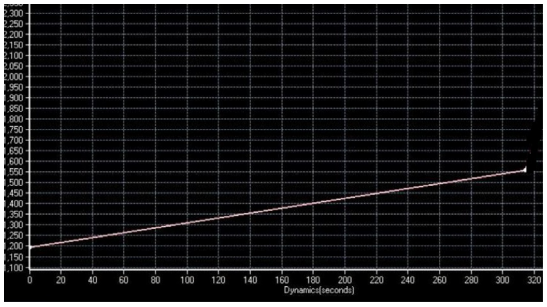
(d) DWI (echo planar(TR/TE,5000/70)



(e) ADC

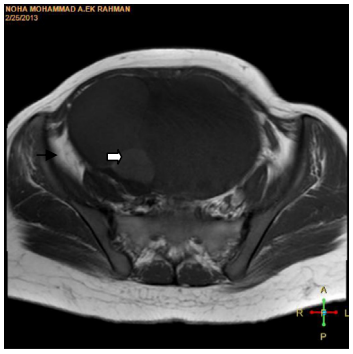


(f) T1post contrast gradient echo(TR/TE,500/5)

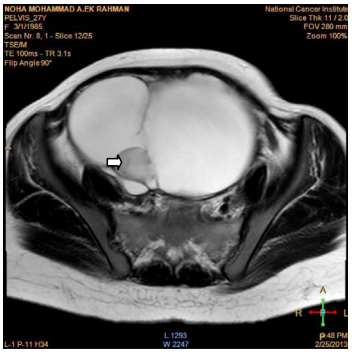


(g) dynamic curve

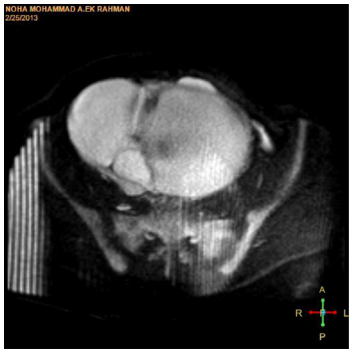
Case 2 27 year-old female patient complaining of infertility for 2 years. US showed left complex cystic adnexal mass lesion with soft tissue nodule. Conventional MRI (a–c) confirmed the presence of left adnexal cystic lesion with posterior wall nodule (arrow). The cyst elicited low signal on T1 and high signal T2, the nodule showed high signal on T1 and T2 with low signal in fat suppression denoting fat content (a benign looking left ovarian mass, likely teratoma). The lesion showed low signal on DWI (d) except the posterior nodule that showed high signal on DWI with low signal on the corresponding ADC maps (e). ADC value of the tumor was 0.6×10^{-3} mm^2/s. That means restriction (malignant lesion). (f & g) The lesion showed faint wall enhancement and the curve showed the criteria of benign lesion in the form of: slow rising curve (type 1), with no definite peak, and MRE 70%. According to conventional and DCE-MRI the lesion is a benign looking left adnexal cystic lesion likely dermoid. Pathology revealed: mature teratoma (benign germ cell tumor).



(a) axial spin echo T1 (TR/TE , 500/10 ms)

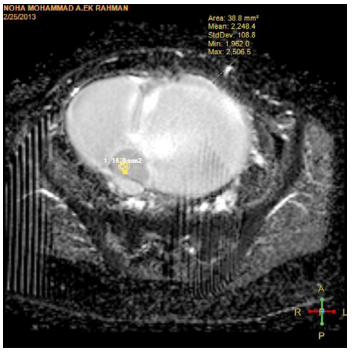


(b) axial T2(TR/TE , 3300/100 ms)

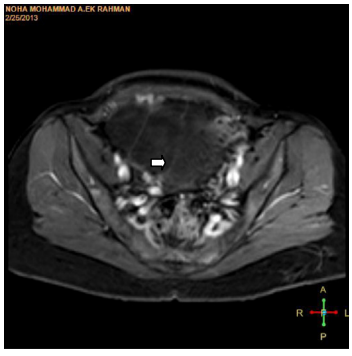


(c) DWI(echo planar(TR/TE,5000/70)

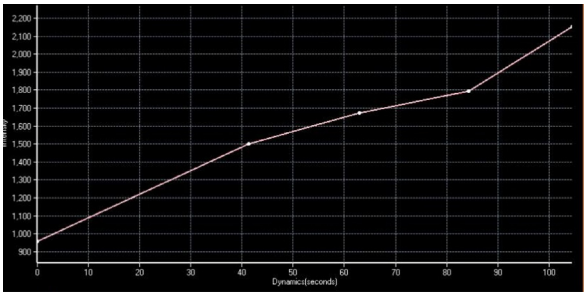
(d) EADC



(e) ADC

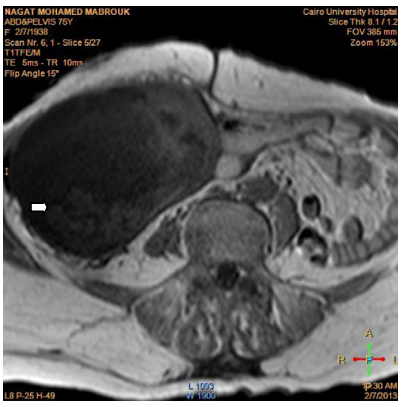


(f) T1post contrast gradient echo(TR/TE,500/5).

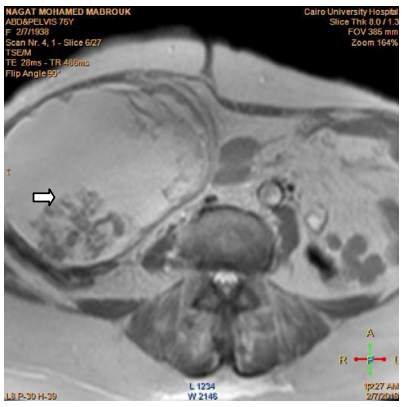


(g) dynamic curve

Case 3 28 year-old female patient complaining of abdominal swelling. US showed a large complex adnexal mass with thick septations and solid component. Conventional MRI (a & b) showed a well defined right adnexal lesion, dominantly cystic with thick septations (3 mm or more) and small posterior solid component on the right side. It elicited low signal on T1, high signal on T2 (arrowed). DWI (c–e): the tumor showed slight high signal on DWI (c), with low signal on the EADC {white arrow (e)}, and slight high signal on the corresponding ADC maps (f), (facilitated) denoting its benignity. (ADC value of the tumor is 2.31×10^{-3} mm^2/s). DCE-MRI (f & g): the lesion showed faint wall and septal enhancement (arrow) and the curve showed the criteria of benign lesion in the form of: slow rising curve (type 1), with late peak at 100 s, and MRE 85%. Diagnosis according to conventional MRI: right malignant looking, ovarian lesion, likely serous cystadenocarcinoma. Diagnosis according to DWI and DME-MRI is benign ovarian lesion. Pathological diagnosis: struma ovarii (benign ovarian cyst contains thyroid tissue).

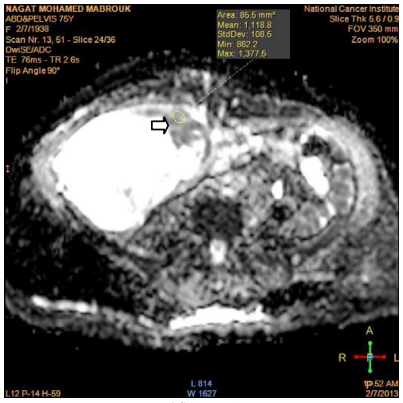


(a) axial spin echo T1 (TR/TE , 500/10 ms)



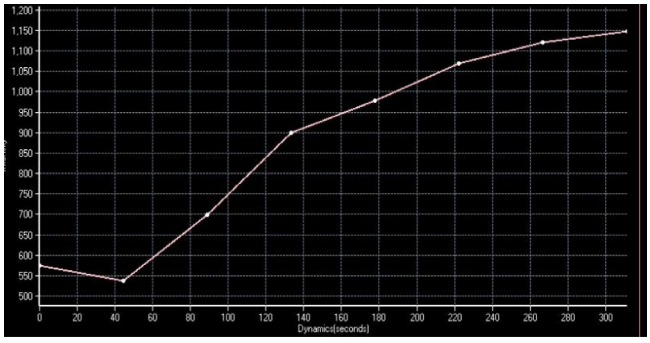
(b) axial T2(TR/TE , 3300/100 ms)

(c) DWI (echo planar(TR/TE,5000/70)



(d)ADC

(e) T1post contrast gradient echo(TR/TE,500/5)



(f)dynamic curve

Case 4 50 year-old female patient complaining of vague pelvic pain. US showed complex right adnexal mass. MRI was done conventional MRI (a & b) showed a large complex right adnexal lesion with multiple papillary projections. It elicited low signal on T1, and high signal on T2, the projection showed slightly increased signal at T1 and reduced signal at T2 (arrow). Conventional MRI based diagnosis is malignant looking right cystic ovarian lesion with possible hemorrhage. DWI (c & d): some areas of the lesion showed high signal on DWI (c) with low signal on the corresponding ADC map (d) {restricted (arrowed lesion)}, suggestive of malignant lesion. ADC value of the tumor was 1.1×10^{-3}mm^2/s. DCE-MRI (e & f): the lesion showed faint wall enhancement and the curve showed the criteria of benign lesion in the form of: slow rising curve (type 1), with late peak at 110 s, and MRE 90%. Diagnosis according to conventional and DWI is malignant looking right complex cystic ovarian lesion unlike the benign criteria seen at DME-MRI. Pathological diagnosis: complicated functional cyst with hemorrhagic infarction (chronic strangulation).

tumor, enhancement of the solid component if present, wall thickness and regularity of the tumor and its enhancement, presence of vegetation and septations, their enhancement pattern and their size. MR images were analyzed for the presence of ascites, presence of infiltrated pelvic or para aortic lymph nodes, involvement of other pelvic organs and presence of peritoneal and omental deposit.

Suggestive MRI signal for benign masses:

- Simple cystic tumors show low signal intensity in T1-weighted images and high signal intensity on T2-weighted images with no solid component.
- Complex benign looking masses: high signal intensity on T1WI is considered either fat or blood. On fat suppressed images low signal is noted with fat while high signal is still noted in blood.

Malignant MR criteria according to (5): presence of wall thickness >3 mm, solid vegetations more than 1 cm. Thick septa >3 mm and areas of necrosis and breaking down. Signs of tumor spread for staging: enlarged lymph nodes, ascites, peritoneal and omental deposit. Post contrast images were used for the recognition of enhancement of the solid component, the tumor wall, septations and vegetations.

3. Interpretation of DWI

3.1. Qualitative analysis

Regarding the signal intensity: we comment if the lesion shows low signal intensity on diffusion images with high signal in the corresponding ADC maps (facilitated) for benign masses or shows high signal intensity on diffusion images with lowering of the signal in the corresponding ADC maps (restricted) for malignant masses.

3.2. Quantitative analysis

Regarding the quantitative analysis of DWI, we generated the ADC map, then we selected the ROI (region of interest) manually on the solid and the cystic component of the tumors, which was then automatically calculated on the work station to get the ADC values. According to a study done by Li and colleagues in 2011 (9), mean ADC value for benign lesions was $1.69\times10^{-3}\pm0.25\times10^{-3}$ mm^2/s, and for the malignant was $1.03\times10^{-3}\pm0.22\times10^{-3}$ mm^2/s with cut off value 1.25×10^{-3}.

4. Interpretation of DCE-MRI

4.1. Analysis of dynamic contrast-enhanced MR images

Dynamic data were analyzed in consensus at a workstation. The entire adnexal mass is included in the five-point dynamic run acquisition at 0, 30, 60, 90, and 120 s after gadolinium injection. A region of interest (ROI) is manually drawn over the most avidly enhancing solid component, thick enhanced wall or septations of the lesion. Signal intensity (SI)–time curve was performed.

4.2. Quantitative dynamic contrast-enhanced MR Imaging

The maximum relative enhancement and the time peak of the curve were reported to know if there was an early uptake (within the first 60 s) or not and if the maximum relative enhancement was more than 85% (with malignant) or less.

Data were statistically described in terms of mean ± standard deviation (±SD), median and range, or frequencies (number of cases) and percentages when appropriate. Comparison of numerical variables between the study groups was done using Student's t test for independent samples. For comparing categorical data, Chi square (χ^2) test was performed. Exact test was used instead when the expected frequency is less than 5. Accuracy was represented using the terms sensitivity, specificity, +ve predictive value, −ve predictive value, and overall accuracy. In addition, comparison between groups was performed using the unpaired t test and McNemar test. Correlations were sought using the Pearson correlation. A $p<0.05$ was considered statistically significant. All statistical calculations were done using computer programs SPSS (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA) version 15 for Microsoft *Windows Image Evaluation*.

3. Results

This study included 30 patients. The statistics included 28 cases, as 2 cases were ovarian mimics, not true ovarian masses, one case was hydrosalpinx, and the other case was broad ligament fibroid. The patient's age ranged from 13 to 70 years (mean age 38.85 ± 17.1 SD). The age in cases with benign tumors ranged from 25 to 62 years (mean age 36). While the age in cases with malignant tumors; ranged from 13 to 70 years (mean age 45). Twenty-three (23 cases) were pathologically proved. The tumors pathologically were classified into: 12 benign and 11 malignant tumors. Benign tumors included 3 serous cystadenomas, 2 endometriomas, 2 post-operative complications (in the form of seroma and fibrosis), 2 mature cystic teratomas, 1 mucinous cystadenoma, 1 struma ovarii, and 1 hemorrhagic infarction in simple cyst. Malignant tumors

Table 1 Different histological types.

		Frequency	Percent	Valid percent
Histology				
Valid	Endometrioma	2	7.1	8.7
	Mature teratoma	2	7.1	8.7
	Immature teratoma	1	3.6	4.3
	Struma ovarii	1	3.6	4.3
	Hemorrhagic infarction in simple cyst	1	3.6	4.3
	Dysgerminoma	3	10.7	13.0
	Serous cystadenoma	3	10.7	13.0
	Serous cystadenocarcinoma	2	7.1	8.7
	Mucinous cystadenoma	1	3.6	4.3
	Mucinous cystadenocarcinoma	5	17.9	21.7
	PostOp. complication(fibrosis)	2	7.1	8.7
	Total	23	82.1	100.0
Missing		5	17.9	
Total		28	100.0	

Table 2 Represents the pathological types according to MRI.

		Frequency	Percent
Conv. MRI mass			
Valid	Benign	13	46.4
	Malignant	15	53.6
	Total	28	100.0

Table 3 Represents results of conventional MRI compared to pathology.

Item	TP	FN	TN	FP	Sensitivity	Specificity	(+) ve PV	(−) ve PV	Accuracy
Conv. MRI # pathology	10	1	7	5	90.91	58.33	66.67	87.50	73.91

included 5 mucinous cystadenocarcinomas, 3 dysgerminomas, 2 serous cystadenocarcinoma, and 1 immature teratoma. Table 1 shows histological types. Missing cases that were not pathologically proved with no surgical excision, just follow up (hemorrhagic cysts). The tumors varied in their composition from being solid, complex cystic, mixed cystic and solid tumors. Ten cases showed typical criteria of malignant lesions by MRI. As size more than 6 cm, wall thickness and septae more than 3 mm and solid vegetation more than 1 cm. Five cases suspected to be malignant by MRI according to size, thick septae and solid nodule were proved to be benign by pathology (one serous cystadenoma, 1 mature teratoma, 1 struma ovarii, 1 hemorrhagic infarction in coplicex cyst, post-operative fibrosis). Cases of post operative fibrosis were seen by conventional MRI and DCE-MRI as fluid collections (blood signal) and septations with areas of restricted diffusion but surgery was done for exploration. One case was suspected to be benign by MRI as it did not show any septations or solid nodule. It proved to be malignant {false negative (pathology was mucinous cystadeno carcinoma)}. Tables 2 and 3 showed pathological types according to MRI and results of conventional MRI compared to pathology. Fourteen cases showed restriction by DWI (high signal in diffusion images, low signal in corresponding ADC map and low ADC values ranging from 0.6 to 1.1 with average 0.8×10^{-3}), 11/14 proved to be malignant by pathology. 3/14 were false positive (2 mature teratomas with ADC values 0.8 and 0.9×10^{-3} and chronic infarction in functional cyst with ADC value 1.1×10^{-3}). Seven cases showed facilitated diffusion (low signal in diffusion images, high signal on corresponding ADC map and high ADC values range from 1.3 to 3 with average 1.8×10^{-3}), all these cases proved to be benign pathologically (Table 4). Five hemorrhagic cysts (diagnosed by MRI criteria and follow up U/S) and 2 endometriomas (proved pathologically) showed high signal not only on diffusion images but also on corresponding ADC map and ADC values $1.3–1.4 \times 10^{-3}$ mm and the cut off value was 1.2×10^{-3}.

Tables 5 and 6 showed comparison of ADC values between benign and malignant cases and results of DWI compared to pathology.

In our study 27 cases underwent dynamic study 22/27 cases were pathologically proved.

Six cases showed plateau curve with time of peak range from 30 to70 s with average 53 s and MRE range from 100% to 180% with average 130% proved pathologically to be malignant. Table 7 showed different curve types and their

Table 4 Represents the pathological types according to DWI.

		Frequency	Percent
Diffusion criteria			
Valid	Benign	14	50.0
	Malignant	14	50.0
	Total	28	100.0

Table 7 Represents different curve types and their percent.

		Frequency	Percent
Curve type			
Valid	Slow rising	11	39.3
	Plateau	16	57.1
	Total	27	96.4
Missing		1	3.6
Total		28	100.0

Table 8 Represents the pathological types according to dynamic criteria.

		Frequency	Percent
Dynamic criteria			
Valid	Benign	20	71.4
	Malignant	7	25.0
	Total	27	96.4
Missing	Missing	1	3.6
Total		28	100.0

Table 5 Shows the comparison between the ADC values between benign and malignant tumors.

ADC	Mean	N	Std. deviation	Minimum	Maximum	Median
Benign	1.864	14	0.5852	1.3	3.0	1.850
Malignant	0.843	14	0.1651	0.6	1.1	0.850
Total	1.354	28	0.6697	0.6	3.0	1.200

Table 6 Represents results of DWI compared to pathology.

Item	TP	FN	TN	FP	Sensitivity	Specificity	(+) ve PV	(−) ve PV	Accuracy
DWI # pathology	11	0	9	3	100.	75.00	78.57	100	86.96

Table 9 Shows the comparison between the MRE values between benign and malignant tumors.

MRE	Mean	N	Std. deviation	Minimum	Maximum	Median
Benign	73	20	22.9	40	140	70
Malignant	130	7	27	100	180	128
Total	88	27	34.9	40	180	80

Table 10 Shows the comparison between the time of peak values between benign and malignant tumors.

Time of peak	Mean	N	Std. deviation	Minimum	Maximum	Median
Benign	92	20	14.3	70	110	95
Malignant	53	7	14.3	30	70	60
Total	82	27	22	30	110	90

Table 11 Represents results of conventional DCE-MRI compared to pathology.

Item	TP	FN	TN	FP	Sensitivity	Specificity	(+) ve PV	(−) ve PV	Accuracy
DCE # pathology	6	4	11	1	60	91	85	73.2	77.2

percentages. The eleven true negative cases showed time of peak range from 70 to 110 s with average 92 s, and MRE range from 40% to 140% with average 73%. 8/11 showed slow rising curves, 3/11 showed plateau curve. Four cases showed plateau curve with late time of peak (80–90) seconds and low MRE (60–75%), were suspected to be benign by the dynamic criteria. Pathology proved the malignant nature of the lesions (3 of them were mucinous cystadenocarcinoma, one was dysgerminoma). One case showed plateau curve with peak time at 60 s and MRE 110%, dynamic criteria suggested to be malignant but the pathology revealed benign lesion (serous cystadenoma (Tables 8–11).

4. Discussion

Ovarian cancer is a leading cause of death among women. It is the second most common gynecological cancer and the fifth most common cancer in women. Unfortunately most women are diagnosed with late stage disease, which has a poor survival rate. Proper diagnosis of cancer can help in finding more available treatment options and in turn better prognosis (3). Proper management depends on proper preoperative assessment, with the help of clinical examination, laboratory tests and different imaging modalities. Thus, helps to inform the patient about the surgical route and the feasibility of conservative treatment (15). Accurate characterization of an adnexal mass as being benign can avoid unnecessary surgery especially in postmenopausal women and can help young women wishing to preserve childbearing potential to go for conservative surgery (14).

MR imaging has shown to be more specific and accurate than US and Doppler assessment in characterizing adnexal masses. In addition, it is the best method in delineation of local spread to the pelvic organs. (4). DWI is one of the promising new functional imaging techniques. As long as interpretation of DWI is combined with the conventional MR images and with realizing of the possible pitfalls, it has shown to be effective in the differentiation of benign from malignant adnexal masses (15). In this study according to DWI: the sensitivity of MRI was 99.9% while that of DWI was 100%. The specificity was higher for DWI (75%) compared to conventional MRI sequences (58.3%), as well as the accuracy which was 73.9% for MRI while that of DWI was 86.9% and so addition of DWI to the MRI is expected to increase the specificity and the accuracy of examination. The mean ADC values for malignant lesions were ($0.84 \times 10^{-3} \pm 0.1$ SD mm^2/s), while that for benign lesions were ($1.8 \times 10^{-3} \pm 0.5$ SD mm^2/s), with cut off 1.2×10^{-3} and p value = 0.00. However p value < 0.05 was considered statistically significant. Mature teratomas showed restricted diffusion with ADC values 0.8×10^{-3} mm^2/s. (false positive), due to mixed cellularity of the teratoma. Hemorrhagic cysts and endometriomas showed high signal not only on diffusion images but also on corresponding ADC map and ADC values 1.3 to 1.4×10^{-3} which can be explained as T2 Shine-through. A study was carried out by Koyama and colleagues in 2007 (6) on 35 women to determine the accuracy of DW imaging in the characterization of ovarian masses in patients undergoing pelvic MRI. The study included 26 benign tumors, 8 malignant tumors and 1 borderline tumor. Malignant lesions only showed definite high signal intensity in DW images. Addition of DWI to conventional MRI has increased the specificity from 81% to 85%, respectively which is comparable to our study where the specificity increased from 58.3% to 75%. In their study the sensitivity of both (MRI and DWI) was 100%. In our study, there were three false positive cases while in their study they excluded the teratomas and hemorrhagic cysts. Another study was conducted by Fujii and colleagues in 2008 (2) on 123 ovarian lesions including 42 malignant and 81 benign lesions, most malignant ovarian tumors as well as some of the mature cystic teratomas showed high signal intensity on DWI. In contrast, most benign tumors did not show abnormal high signal intensity on DWI. This agrees with our results that all the malignant lesions (11 cases) and two cases of mature cystic teratomas showed high signal on DWI, this may be attributed to keratinoid substance. In 2008 (14), Thomassin-Naggara et al. evaluated the contribution of DWI in conjunction with morphological criteria to

characterize 77 complex adnexal masses (30 benign and 47 malignant). In their results, low signal intensity both on DWI and T2-weighted images in the solid component of mixed adnexal masses may predict benignity. They concluded that the decreased mean ADC values in benign lesions may be attributed to dense network of collagen fibers within the extracellular matrix in benign fibrous tumors which were included in their study, as fibromas, Brenner tumors, and cystadeno fibromas. In our study all the benign tumors did not show high signal on DWI except for 2 cases of mature teratomas and one case diagnosed as chronic infarction in simple cyst. A similar study was carried out by Takeuchi and colleagues in 2010 (13) on 47 women (33 malignant, 6 borderline, and 10 benign tumors). Regarding the signal intensity all malignant tumors showed high intensity on DWI, whereas only 3 cases of the benign tumors (3 thecomas) showed high intensity. However the presence of low intensity on T2-weighted images was suggestive for benign fibrous tumor. The mean (SD) ADC value in malignant tumors (1.03×10^{-3} (0.19) mm^2/s) was significantly lower than that in the 10 benign tumors 1.38×10^{-3} (0.30) mm^2/s. Using a cutoff ADC value of 1.15, malignant lesions had a sensitivity of 74%, specificity of 80%, PPV of 94%, and NPV of 44%. Another study was carried out by Li and colleagues in 2011 (9) on 127 patients with pelvic masses, (46 benign and 85 malignant). The purpose of this study was to evaluate differences in ADC values for the solid component of benign and malignant ovarian surface epithelial tumors with the goal of differentiating benign versus malignant ovarian tumors preoperatively. The mean ADC value measured for the solid component significantly differed between the benign and malignant lesions. Mean ADC value for benign lesions was $1.69 \times 10^{-3} \pm 0.25$ SD mm^2/s, and for the malignant was $1.03 \times 10^{-3} \pm 0.22$ SD mm^2/s. The lower ADC values associated with the malignant group were found to be statistically significant. Their results suggest that an ADC value $\geqslant 1.25 \times 10^{-3}$ mm^2/s may be an optimal cutoff value for differentiating benign and malignant ovarian tumors. In our study, the mean ADC value for solid malignant lesions was $0.8 \times 10^{-3} \pm 0.11$ SD mm^2/s, while that for solid benign lesions was $1.8 \times 10^{-3} \pm 0.5$ SD mm^2/s, with 1.25×10^{-3} mm^2/s may be a cutoff value for differentiating benign and malignant ovarian tumors. Also in their study, the sensitivity, specificity, PPV, NPV and accuracy of conventional MR imaging all have increased from 91.8%, 78.3%, 88.6%, 83.7%, and 87.0%, respectively to 96.5%, 89.1%, 94.3%, 93.2%, and 93.1% after adding DWI to the conventional MR. This was comparable to our study. Addition of DWI to conventional raises the specificity, PPV, NPV and accuracy from 58%, 66, 87% and 73% to 75%, 78%, 100% and 86%.

4.1. According to DCE-MRI

In our study the sensitivity of MRI was 99.9% while that of DCE-MRI was 60%. The specificity was higher for DCE (91%) compared to conventional MRI sequences (58.3%), as well as the accuracy which was 73.9% for MRI while that of DCE was 77% and so addition of DCE to the MRI is expected to increase the specificity and the accuracy of examination. There was an overlap between benign and malignant lesions according to the type of curve, as plateau curve was found on 16/27 cases, 11 cases were malignant. According to malignant lesions, time of peak ranged from 30 to 70 s with average 53 s and MRE ranged from 100% to 180% with average 130%. According to benign lesions, time of peak ranged from 70 to110 s with average 92 s, and MRE ranged from 40% to 140% with average 73%.

In 2003 (12), Sohaib and colleagues described that Malignant lesions show greater enhancement than benign lesions during the early phase of enhancement rather than the late phase of enhancement while benign ovarian tumors showed a gradual increase in enhancement without a well-defined peak, while, borderline ovarian tumors showed moderate initial enhancement followed by a plateau. A study done by Livia and colleagues in 2011 (8) described that there was some overlap in the enhancement pattern between benign and malignant groups using all the semi-quantitative parameters (peak time and MRE), however most of malignant lesions showed peak time at 60 s or less and average MRE was 80 or more findings that is comparable to our study. The sensitivity was 67%, specificity was 88%, matching with our results, PPV of their study was 86% and NPV was 71%. There were 3 false positives: a Brenner tumor, a struma ovarii and an abscess. There were 12 false negatives. In our study there were 4 false negative cases (3 of them were mucinous cystadeno carcinoma, one was dysgerminoma). One false positive case (serous cystadenoma). Another study was carried out by Pegah and colleagues in 2012 (11) on 65 patients with pelvic masses, (36 benign and 22 malignant and 7 border line). A plateau curve, was mostly seen with borderline, benign tumors and 11 malignant cases, the other 11 malignant cases showed rapid, steep, early enhancement followed by washout. The initial areas under the curve within the first 60 s (IAUC-60) were significantly higher for invasive lesions than they were for benign and borderline masses (sensitivity, 93.7%; specificity 88%). In our study the cutoff value for peak time was 75 s, this may be due to manual technique of contrast injection.

5. Conclusion

Combination of DWI and DCE to conventional MRI implies: using a completely noninvasive technique with no radiation exposure. It improves the specificity of MRI and thus increasing radiologist's confidence in image interpretation which will finally reflect on patients' outcome and prognosis. According to DWI might be an alternative for contrast administration especially for those were contrast intake is better avoided as during pregnancy. Cost effective technique (no additional cost to MRI examination), was easily added to the MR study protocols with no marked lengthening of examination time.

Conflict of interest

None declared.

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