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Original Article

Adding Value of Diffusion Weighted Imaging with Background Signal Suppression {DWIBS} in Loco-Regional Staging of Gynecological Cancers

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ABSTRACT

Background: Further research into further diagnostic techniques for tumor histological type seems crucial because the histology of the tumor may have a substantial impact on the treatment plan and surgical strategy selected. This study investigated adding values of diffusion weighted imaging with background signal suppression (DWIBS) sequence to the conventional MRI protocol in assessment and loco-regional staging of different gynecological tumors.

Methods: This study included 55 patients with a confirmed diagnosis of any gynecologic neoplasm with preoperative staging by the conventional MRI and DWIBS with high b value (1500 s/mm^2).

Results: The examined 55 Patients were divided according to the final histopathological diagnosis into ovarian, cervical, endometrial and vulvar tumors. In conventional DWI, there was overlap as regard borderline ovarian tumors that shows false restriction, with significant difference between the conventional DWI results in early stages of FIGO staging system (stage IB and IIA P=0.031 and 0.016 respectively), while DWIBS shows accurate assessment of borderline ovarian tumors and early stages of FIGO staging system with no-significant difference between it and the histopathological results (p>0.05).

Conclusions: DWIBS can support and boost the accuracy of MRI in identifying or ruling out possible malignancy in gynecological neoplasms. DWIBS is useful in detection of borderline ovarian tumors that are not restricted at DWIBS and falsely restricted in the conventional DWI. Also, DWI plays an important role in loco-regional staging of gynecological tumors especially at early stages and that would enable strategies to retain fertility in young women and limit unwanted radiation.

Keywords: MRI; DWIBS; Gynecological Cancers.

INTRODUCTION

Diffusion Weighted Imaging (DWI) is a functional MR imaging technique used to show tissue feature dependent on water particles arbitrary dissemination movement, reflects alterations in proton mobility due to different pathological conditions **[1]**. The low signal-to-noise ratio and susceptibility artifacts that are connected to echo-planar imaging are its two main drawbacks, so many other strategies are used for optimizing signal-to-noise ratio. in 2004, **Takahara et al [2]** developed a technique named “diffusion weighted imaging with background signal suppression (DWIBS)”, to produce thin-layer DWI. Compared to the conventional DWI, it takes slightly longer time to provide multilevel stimulation and signal avenge time and can effectively inhibit fat by using short T1 inversion recovery (STIR) echo planer imaging (EPI) sequence that improve the quality of whole-body three-dimension (3D) reconstruction imaging. Moreover, DWIBS is less susceptible to signal loss and air-tissue border artifacts.

The strength of the diffusion sensitizing gradient is represented by the (b-value). When a low b-value of less than 100 s/mm2 is used, signal loss occurs in purely cystic lesions or in highly mobile water molecules like those found in arteries. Thus, a low b value will show the effect of both perfusion and diffusion effects. Water flow is restricted in highly cellular tissues. Water molecules in such tissue retain signal intensity even at high b values (500–1000 s/mm 2). Using higher b values reflects true diffusion in the tissue. It is good for separating these components **[3]**.

Gynecologic cancers are the 2nd most common cause of morbidity in women globally, after breast cancer. Many women with gynecologic cancer die from recurrence despite receiving intensive treatment **[4]**. Cancers of the uterus, ovaries, fallopian tube, cervix, vulva, and vagina are classified as gynecologic cancers, and they vary in frequency, location and are among the cancer-related leading death worldwide **[5]**.Magnetic resonance imaging (MRI) is a reliable imaging technique for preoperative assessment of different gynecological neoplasms, it helps in diagnosis of the origin of the gynecological tumor (ovarian, cervical, endometrial…etc), its extension, grading, lymph nodes involvement **[6]**. Recent staging updates from "the International Federation of Gynecology and Obstetrics, or FIGO (Fédération Internationale de Gynécologie et d'Obstétrique)" recognize the importance of radiological imaging, particularly molecular imaging, for precise staging of various gynecological cancers **[7]**.

The study aimed to determine feasibility of utilization of DWIBS sequence in addition to the conventional MR imaging protocol in assessment of gynecologic tumors and their loco-regional staging.

METHODS

This study included 55 female patients. The ages of the examined cases ranged from 18 to 73 years old. They were referred from "Obstetrics and Gynecology department" to Radiodiagnosis department Faculty of medicine in our institution, during nine months (between March to December 2023), following receipt of our hospital's institutional board review (IRB number: 10737) with the patients' informed consent obtained before to the study, the study was conducted according to the declaration of Helsinki on Biomedical Research Involving Human Subjects.

Patients with contraindication for MRI (such as claustrophobia, ferromagnetic foreign material, implanted pacemaker, cochlear implants, aneurysmal clips…etc.) were excluded from the study.

All patients underwent clinical assessment including age, complaint, course of the disease, duration, past and family histories, then underwent conventional MRI in addition to DWIBS, finally histopathological assessment.

Radiological assessment:

MR examination was performed by using a 1.5T machine and surface body coil system (GE). The patient was in a supine position throughout the examination.

a) Technique of examination:

Patients were positioned in supine position and were instructed not to move during the examination. Surface coil was placed over the pelvis.

b) MRI protocol:

1-Precontrast T1 and T2WI sequences:

Localizer images in axial, coronal and sagittal planes. Fast spin echo T1-weighted echo (FSE) (TR 497ms, TE 12 ms, matrix 320 ×512, slice-thickness: 4-5mm with an interslice gap of 1–2 mm, FOV 250mm and a flip angle of 90) in axial, coronal and sagittal planes. Fast spin echo T2-weighted images (FSE) (TR 3060 ms, TE 90 ms, matrix 256×512, slice-thickness: 4-5mm with an interslice gap of 1–2 mm, FOV 250mm a flip angle of 90) in axial, coronal and sagittal planes

2-Diffusion weighted imaging:

DWI was done by using a single-shot spin-echo type echo planar sequence under free breathing with the following parameters (TR/TE 3200/72, matrix 512×512, slice-thickness 4mm with an interslice gap of 1mm and FOV 300 mm, b value 800 sec/mm2), were acquired on the axial plane. ADC maps were automatically reconstructed for all diffusion weighted images and used for the measurement of ADC value.

3-Diffusion weighted imaging with background signal suppression:

DWIBS was done by utilizing the single-shot-echo-planar sequence in the axial plane with the following parameters (TR 8459 ms, TE 180ms, slice thickness 6mm, space 1 mm, FOV 360x400x276mm, with high b-value about 1500 sec/mm2).

4-Post-contrast sequences:

Intravenous injection of Gadolinium Diethylene Triamine Penta Acetic acid (GD-DPTA) with dose 0.1-0.2 mmol /kg BW. Post contrast axial and sagittal T1 spin echo with fat suppression were performed utilizing the following parameters (TR 621ms, TE 18 ms, matrix 205×512, slice-thickness: 4-5mm with an interslice gap of 1–2 mm, FOV 280mm and a flip angle of 90).

The following parameters were examined in the MR images: the tumor's appearance, the location of the lesion, the tumor's signal intensity, the tumor wall thickness and pattern of enhancement, solid component, the presence of ascites, the size and pattern of the vegetations' enhancement, the involvement of other pelvic organs, the presence of peritoneal and omental deposits, and pelvic or para-aortic lymph nodes involvement.

Histopathological correlation:

The MRI findings including results of DWIBS for all patients were correlated with the histopathological results obtained after laparoscopic/ surgical biopsies.

STATISTICAL ANALYSIS:

SPSS is used for data management. Released in 2015 by IBM Corp., Version 23.0 of IBM SPSS Statistics for Windows IBM Corp., Armonk, NY. P-values greater than 0.05 were deemed statistically significant (S), whereas P-values lower than 0.05 were deemed statistically insignificant (NS).

RESULTS

This study included 55 female patients with gynecological neoplastic lesions, their ages ranged from 18 to 73 years old. The MRI results showed that patients had ovarian, cervical, and uterine tumors in 24, 18, and 12 cases, respectively; only one case had a vulvar (perineal) tumor.

They presented by irregular vaginal bleeding, postmenopausal bleeding, vaginal discharge, pelvic mass, or pain, and perineal mass with incidence about 27.2 %, 21%, 5%, 25%, 20%, and 1.8% respectively, the most presenting symptom was the irregular vaginal bleeding that was presented in about (27.2%) (**table 1**).

From all 24 ovarian tumors, 10 cases were benign, 3 cases were borderline and the other 11 cases were malignant by histopathology. Regarding cervical tumor, all the examined 18 cervical tumors were malignant by histopathological results (15 squamous cell tumor and 3 adenocarcinoma). All examined 12 uterine tumors were endometrial carcinomas (9 endometrioid adenocarcinoma and 3 serous adenocarcinoma) by histopathological results. The histopathology of the case with vulvar lesion was diagnosed as epidermoid tumor (**table 2**).

Regarding conventional MRI findings, ovarian tumors possess distinct forms; solid, complex (cystic and solid), and cystic masses, 54.2% and 37.5% of lesions presented by low and heterogeneous SI at T1WI respectively, only (8.3%) show high SI at T1WI (they were mucinous cystadenoma by histopathogical results). Ovarian masses were typically hyperintense or heterogeneous at T2WI (41.7% and 58.3% respectively). In post contrast they showed heterogeneous and wall enhancement (70.8% and 29.2% respectively). On the conventional DWI 17 lesions were restricted with false positive 6 cases (proved histopathologically to be 3 mature cystic teratomas and 3 borderline serous cystadenomas), while on DWIBS only 14 lesions were restricted with false positive 3 cases (proved histopathologically to be mature cystic teratomas) (**table 3**). The borderline serous cystadenomas were not truly restricted at DWIBS **(figure 1).**

As regard to cases of cervical carcinomas, most of the lesions were of intermediate or high signal intensity on T2WI (55.6% versus 27.8%, respectively) compared to the myometrium, with heterogeneous SI was found in big tumors due to necrosis (16.6%). On post contrast sequences, all displayed early avid enhancement compared to unaffected cervical tissue. Tumors of small size exhibited uniform enhancement, while those of big size displayed uneven enhancement due to necrosis. (44.4% and 55.6% respectively), The lesions in all cases showed restricted diffusion in both conventional DWI and DWIBS (**table 3**). DWIBS provided intense restriction of the mass in contrast to the suppressed background with good delineation of the borders of the cervical tumors **(figure 2).**

Regarding the endometrial carcinoma cases, the lesions were isointense at T1WI 100% **(figure 3)**, while at T2WI 83.3% displayed low SI and 16.7% showed heterogeneous SI compared with the normal endometrium. on post contrast enhancement images, 66.7% of lesions showed heterogeneous enhancement and 33.3% were homogenously enhanced, at both DWI and DWIBS 83.4% were restricted and 16.6% not restricted (**table 3**).

In the case of the vulvar epidermoid tumor, the lesion displayed low SI at T1WI, high SI at T2w image, with ring enhancement at the post contrast study, no mural nodules or soft tissue intensity lesions, it showed restriction at DWI and DWIBS.

Regarding tumor extension and loco-regional staging of the gynecological malignancy (FIGO staging system), there was statistically significant difference between standard MRI with conventional DWI and histopathology in detecting tumor stages I and II ($p<0.05$), while there was no statistically significant difference between results of DWIBS and histopathology, with accurate detection of tumor extension **(figure 3)** especially at early stages ($p>0.05$) (**table 4**).

Table (1): Demographic and clinical data of the studied patients.

		Total (n=55)	Cervical tumor (n=18)	Endometrial tumor (n=12)	Ovarian tumor (n=24)	Valvular tumor (n=1)
Age (years)	**Mean ± SD**	54.24 ± 10.33	53.91 ± 7.42	53.89 ± 6.25	55 ± 13.06	45
	Range	18 - 73	44 - 71	45 - 70	18 - 73	---
Clinical presentation	**Irregular vaginal bleeding**	15 (27.27%)	8 (44.44%)	7 (58.3%)	0 (0%)	0 (0%)
	Postmenopausal bleeding	12 (21.81%)	7 (38.89%)	5 (41.7%)	0 (0%)	0 (0%)
	Vaginal discharge	3 (5.45%)	3 (16.67%)	0 (0%)	0 (0%)	0 (0%)
	Pelvic Pain	14 (25.45%)	0 (0%)	0 (0%)	14 (58.3%)	0 (0%)
	Abdominal Pain	6 (10.90%)	0 (0%)	0 (0%)	6 (25%)	0 (0%)
	Abdominopelvic swelling	4 (7.27%)	0 (0%)	0 (0%)	4 (16.7%)	0 (0%)
	Perineal swelling	1 (1.83%)	0 (0%)	0 (0%)	0 (0%)	1 (100%)

Table (2): Distribution of the studied patients regarding the histopathological results.

		n=55
Cervical tumor (n=18) 32.7%	**Squamous cell carcinoma**	15
	Adenocarcinoma	3
Endometrial tumor (n=12) 21.8 %	**Endometrioid adenocarcinoma**	9
	serous adenocarcinoma	3
Ovarian tumor (n=24) 43.6 %		
	Mucinous cystadenoma	2
	Mature cystic teratoma	3
	Peritoneal inclusion cyst	2
	serous cystadenoma	3
	borderline serous cystadenoma	3
	Serous cystadenocarcinoma	3
	Mucinous cystadenocarcinoma	2
	Endometrioid carcinoma of the ovary	1
	Undifferentiated ovarian carcinoma	2
	Ovarian metastasis	3
Vulval tumor (n=1) 1.9 %	**epidermoid cyst**	1

Table (3): MRI sequence distribution of the studied patients

		Total (n=55)	Cervical tumor (n=18)	Endometrial tumor (n=12)	Ovarian tumor (n=24)	Valvular tumor (n=1)
Malignancy	**Benign**	11 (20%)	0 (0%)	0 (0%)	10 (41.7%)	1(100%)
	Borderline	3 (5.5%)	0 (0%)	0 (0%)	3 (12.5%)	0 (0%)
	Malignant	41 (74.5%)	18 (100%)	12 (100%)	11(45.8%)	0 (0%)
T1	**Isointense/intermediate**	18 (32.72%)	6(33.3%)	12 (100%)	0 (0%)	0 (0%)
	Hypointense	24 (43.63%)	10(55.6%)	0 (0%)	13 (54.2%)	1 (100%)
	Hyperintense	4 (7.29%)	0 (0%)	0 (0%)	2 (8.3%)	0 (0%)
	Heterogeneous	9(16.38%)	2 (11.1%)	0 (0%)	9(37.5%)	0 (0%)
T2	**Isointense/intermediate**	10 (18.18%)	10(55.6%)	0 (0%)	0 (0%)	0 (0%)
	Hypointense	15 (27.27%)	0 (0%)	10 (83.3%)	0(0%)	0 (0%)
	Hyperintense	16 (29.09%)	5(27.8%)	0 (0%)	10(41.7%)	1 (100%)
	Heterogeneous	14(25.46%)	3(16.6%)	2 (16.7%)	14(58.3%)	0 (0%)
T1 post contrast (DCE)	**Homogeneous**	16 (29.1%)	8 (44.4%)	4 (33.3%)	0 (0%)	0 (0%)
	Heterogeneous	35 (63.6%)	10(55.6%)	8(66.7%)	17 (70.8%)	0 (0%)
	Ring (wall) enhancement	4 (7.3%)	0 (0%)	0 (0%)	7(29.2%)	1 (100%)
DWI	**Restricted**	46(83.6%)	18(100%)	10 (83.3%)	17(70.8%)	1 (100%)
	No restricted	9 (16.4%)	0(0%)	2 (16.7%)	7(29.2%)	0 (0%)
DWIBS	**Restricted**	43(78.2%)	18(100%)	10 (83.3%)	14 (58.33%)	1 (100%)
	No restricted	12 (21.8%)	0 (0%)	2 (16.7%)	10 (41.67%)	0 (0%)

Table (4) Comparing Standard MRI, DWIBS, Histopathology for Tumor Staging.

Tumor stage Grades		Diagnostic procedure						p1	p2
		Standard MRI		DWIBS		Histopathology			
		No.	%	No.	%	No.	%		
I	IA	5	11.4	2	4.9	2	4.9	0.25	1
	IB	6	13.6	12	29.3	12	29.3	**0.031**	1
II	IIA	9	20.5	2	4.9	2	4.9	**0.016**	1
	IIB	5	11.4	7	17.1	7	17.1	0.5	1
III	IIIA	1	2.3	0	0	0	0	-	-
	IIIB	5	11.4	5	12.2	5	12.2	1	1
	IIIC	4	9.1	4	9.8	4	9.8	1	1
IV	IVA	3	6.8	3	7.3	3	7.3	1	1
	IV B	6	13.6	6	14.6	6	14.6	1	1

p<0.05: significant, p>0.05: not significant,
McNemr Test P1: Standard MRI with standard DWI & histopathology.
McNemr Test P2: MRI with DWIBS & histopathology.

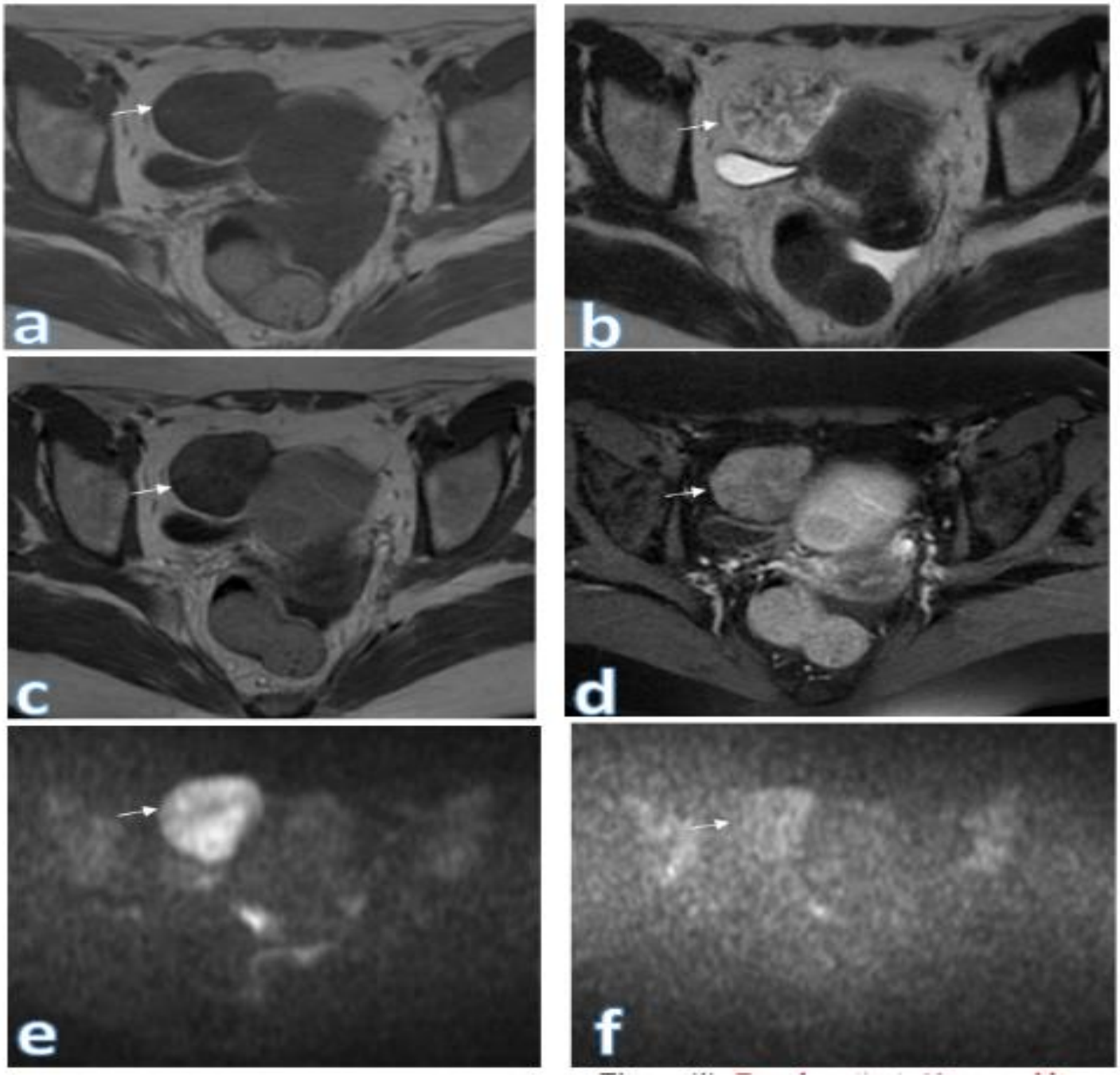
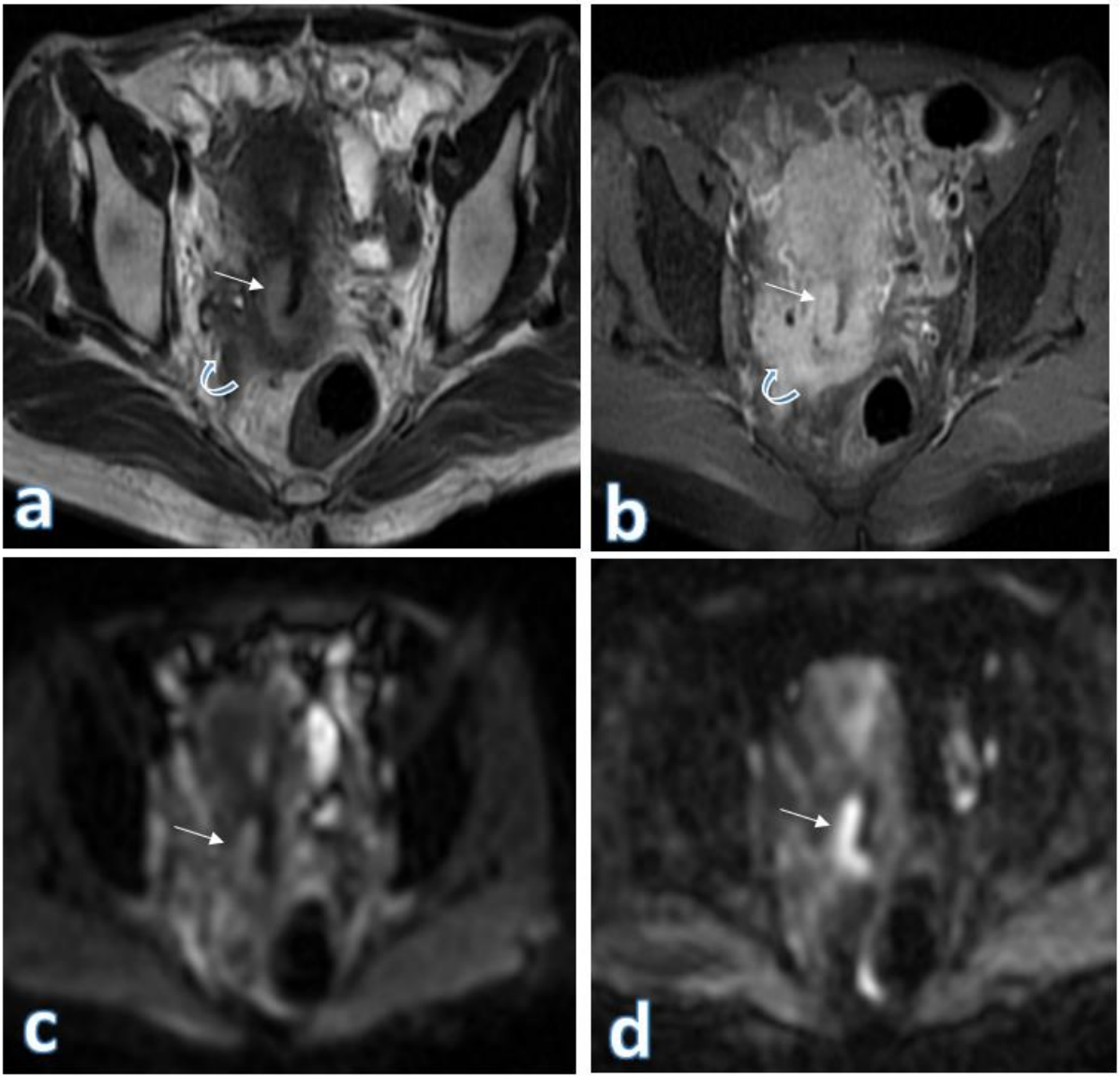


Figure (1): Female patient, 41 years old, presented by chronic pelvic pain, RT ovary shows well defined solid lesion, displays low to intermediate SI at T1WI (a), high SI with solid hypointense papillary projections at T2WI (b) that shows faint heterogeneous enhancement at post contrast images T1WI post contrast and T1WI with fat suppression (c and d respectively), conventional DWI shows intense restriction of the mass with ADC value $1.2x10^{-3}$mm/s. (e), while no significant restriction at DWIBS with high b value 1500 s/mm^2 (f), proved histopathology to be border line ovarian serous cystadenoma.



Female patient, 47 years old, presented by irregular vaginal bleeding with histopathological proved cervical adenocarcinoma on radiotherapy, T2WI shows soft tissue mass at the RT postero-lateral wall of the cervix displays intermediate SI (arrow) with irregularity of the upper vaginal wall and surrounding fat (curved arrow)(a), at post contrast sequences, it shows intense post contrast enhancement of the cervical mass (arrow) and the upper vaginal wall and surrounding tissues (curved arrow) (b), conventional DWI shows faint restriction of the mass and the surrounding tissue (stage IIa)(c), while DWIBS shows restriction of the cervical mass only (arrow), with no detected restriction in the vaginal walls and the surrounding tissue (stage Ib) (d), and that was confirmed by the post-operative histopathological results (stage Ib) with upper vaginal wall swelling and post-radiotherapy changes, while no detected malignant cells. **Figure (2)**

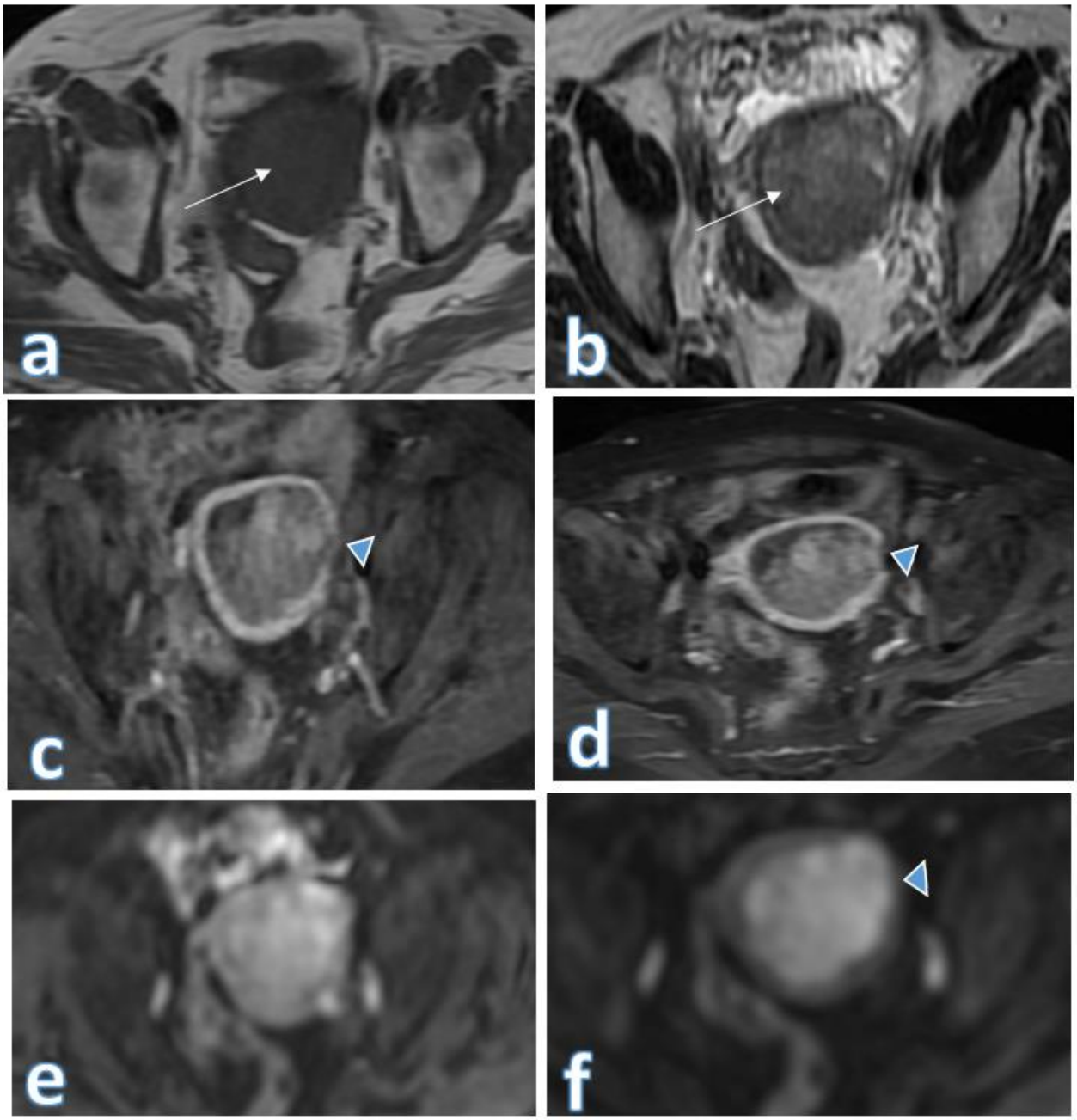


Figure (3): Female patient, 70 years old, presented by post-menopausal vaginal bleeding. T1WI shows bulky uterus (a), T2WI shows endometrial cavity distension with intermediate heterogeneous SI mass with areas of cystic degeneration (b), at post contrast images (c and d) it displays heterogeneous enhancement (arrow), intact surrounding myometrium except for focal thinning and wall defect at the left antero-lateral myometrial wall (arrow head), conventional DWI (e) shows mild restriction with difficult assessment of myometrial invasion (stage Ia), at DWIBS (d), it shows intense heterogeneous restriction of the mass (arrow) with signs of antero-lateral myometrial wall invasion more than 50% (arrow head) (stage Ib), postoperative histopathology proved to be stage Ib with invasion of more than 50 % of myometrium.

DISCUSSION:

Since gynecological malignancies are among the most prevalent neoplasms among women, they represent a significant public health concern. Most women present at advanced stages, which has a negative impact on the prognosis and clinical results. Factors causing poor clinical outcome include varying pathology, a lack of effective screening facilities in developing countries, and a lack of awareness about cancer. Over time, ovarian cancer has become one of the most prevalent cancers to harm women, with an increasing incidence rate. Cervical cancer is still the second most frequent malignancy in women after breast cancer **[8].**

MRI has an established role in local gynecological neoplasm staging. Since traditional DWI imaging methods have limitations, **Takahara et al [2]** developed a novel method called "diffusion-weighted imaging with background signal suppression (DWIBS)" that can obtain PET-like images and achieve an effect like that of positron emission tomography (PET). In our study, the most prevalent tumor was the ovarian tumor (24 patients), then the cervical tumor (18 patients) and the uterine tumors which presented in (12 patients); only one vulvar tumor was included in this study.

Ovarian lesions:

This study included 24 patients with ovarian tumors, their ages ranged from 18 to 73 years with a mean ± SD of 55 ± 13.06 years. They presented clinically with pelvic pain, abdominal pain, and abdominal swelling in 58.3%, 25%, and 16.7% respectively, which agreed with **Kamal et al. [9]** study who found that the most common clinical presentation was pelvic pain in 29 (82.86%) in the examined 35 female patients with ovarian lesions.

In our study conventional MRI revealed that ovarian lesions were hypointense and heterogeneous at T1WI, presented in 54.2 and 37.5 % respectively, and 8.3% of lesions were hyperintense at T1WI, while at T2WI they presented by hyperintense and heterogeneous signal intensities, 41.7% and 58.3 % respectively. This is in agreement with **Kamal et al. [9]** they found that ovarian masses on T1WI showed low signal intensity in 16 (45.71%) patients, high signal intensity in 11(31.43%) patients, intermediate signal intensity in 4 (11.43%) patients, and heterogeneous signal intensity in 4 (11.43%) patients and on MRI T2WI showed hyperintense ovarian masses in 22(62.86%) patients, and heterogeneous hyperintense ovarian masses in 11 (31.43%) patients. Post contrast sequences in our study revealed that 70.8% showed heterogeneous enhancement and 29.2% showed wall/ peripheral enhancement. **Taj-Aldean [10]** described malignant lesions to have complex solid and cystic components, vegetation on the wall, large size, septa inside the cystic adnexal lesion; all result in heterogeneous enhancement at post contrast sequences.

Regarding DWI and DWIBS of ovarian masses in the current study; DWI showed 17 (70.8%) restricted lesions, while 14 (58.33%) restricted lesions were found on DWIBS, with three false positive restricted cases at DWI, proved to be ovarian borderline tumors (papillary serous cystoadenoma) by histopathological results. So, the application of DWIBS with high b value 1500 s/mm2 improves the diagnostic MRI evaluation of ovarian tumors by overcoming the T2 shine through that may be seen in the conventional DWI and increase the signal intensity restriction of malignant tissue in contrast to the suppressed background. In the current study, histopathological examination revealed 10 (41.7%) benign ovarian lesions, the most prevalent were mature cystic teratoma and serous cystadenoma, 3 (12.5%) cases for each lesion, followed by mucinous cystadenoma and inclusion cysts, 2 (8.3%) cases for each lesion. These results agreed with **Tantawy et al. [11],** they found that the most common benign lesion in examined 17 patients with benign ovarian masses was the mature cystic teratoma which was diagnosed in 4 cases after the tubo-ovarian abscess which was found in 7 cases from all examined 17 benign ovarian lesions. Regarding the FIGO staging system for ovarian cancer, there was significant difference between standard MRI and histopathological results at stage I ($P<0.05$), while no significant difference between DWIBS and histopathology in detecting tumor staging in ovarian tumors $p>0.05$. conventional MRI and DWIBS diagnosed the locoregional ovarian staging, which was in agreement with the histopathological results, except in the false 3 borderline ovarian tumors, which were false diagnosed by the conventional MRI as stage IA. This agrees with **Nakayama et al. [12]** who found controversy regarding the usefulness of DWI and ADC mapping in the evaluation of cystic ovarian tumors, particularly for differentiating benign from malignant lesions.

Cervical lesions:

Regarding 18 patients with cervical tumor in the current study, their ages ranged from 44 to 71 years with a mean ± SD of 53.91 ± 7.42 years. Of them, 8 (44.44%) patients had irregular vaginal bleeding, 7 (38.89%) patients had postmenopausal bleeding, and 3 (16.67%) patients had vaginal discharge. Our

results were consistent with that of **Aziz and Yousfani. [13]** their study included 56 cases (33.53%) of cervical cancer with ages ranged between 29 and 73 years with mean age 51 years. The commonest symptoms in their study were irregular vaginal bleeding 27(48.21%), vaginal discharge 25(44.64%), and postmenopausal bleeding in 17(30.35%).

In our study, the conventional MRI showed 10 (55.6%) of cervical lesions were hypointense, 6 (33.3%) of lesions were iso/intermediate signal intensity, and 2(11.1%) of lesions were heterogeneous on T1WI. In line of our result **Sinjawi et al. [14]** found that on T1 weighted images, hypo signal intensity was found in 13 cases (65%), isointense signal intensity was found in 5 cases (25%) and heterogeneous signal intensity was found in 2 cases (10%).

At T2WI, 10 (55.6%) of cervical lesions were iso/intermediate signal intensity, 5(27.8%) were hyperintense, and 3(16.6%) were heterogeneous signal intensity. These results agree with **Sherif et al. [15]** who found that cervical lesions were displayed isointense, hyper intense, and heterogeneous signal intensities at T2WI in 55%, 25%, and 15% respectively.

In our study, heterogeneous post contrast enhancement was seen in 10 (55.6%) lesions, and homogeneous post contrast enhancement was seen in 8(44.4%) lesions, In line of our results **Sinjawi et al. [14]** found that on T1 post contrast enhancement, heterogeneous enhancement was found in 17 cases (85%), homogenous enhancement was found in 3 cases (15%). This is explained by small tumors are homogeneously enhancing, and enhancement occurs earlier than the normal cervical stroma, facilitating tumor detection. Large tumors are frequently necrotic but are often surrounded by an enhancing rim that facilitates tumor delineation **[6].**

In this study, all the examined 18 cervical lesions were malignant with predominant squamous cell carcinomas that were found in 15 patients and only 3 cases with cervical adenocarcinoma. All showed restriction at conventional DWI and DWIBS. However, in cervical cancer FIGO staging, conventional DWI findings showed false staging of 5 cases between stage I, II and IIIA, while all cases were staged correctly with DWIBS with not statistically significant statistically difference between it and the histopathological result ($p>0.05$). In concordant with our results, **Schleder et al. [16]** found that DWIBS improves the signal intensity and increases the signal of cervical tumors in comparison to the suppressed background which leads to more consipiciousity of the tumor. Moreover, it plays an important role in precisely determining the size of tumor, location, and extention, including any pelvic side wall, nodes, or parametrial involvement. This information is useful in identifying patients who may be candidates for conservative fertility preservation procedures, especially young women with FIGO I tumors.

Uterine lesions:

Regarding 12 patients with endometrial tumors in our study, their ages ranged from 45 to 70 years with a mean ± SD of 53.89 ± 6.25 years. Of them, 7 (58.3%) patients had irregular vaginal bleeding and 5 (41.7%) had postmenopausal bleeding. In agree with **Elsammak et al. [17]** study 42 female patients presented with post-menopausal vaginal bleeding (48%), pre-menopausal bleeding (38%) or pelvic pain (14%); Their ages were between 19 and 76 years (mean age: 59.1 + 7.5) and the most common age group was 60–70 years (33.2%) followed by 50–60 years (23.8%).

In conventional MRI, all our examined 12 endometrial tumors were iso to intermediate SI at T1WI, while on T2WI 10 cases were hypointense (83.3%) and 2 cases were heterogeneous (16.7%), these findings were in consistent with prospective study of **Keriakos and Darwish [18]** 25 patients with suspicious uterine tumor (15 endometrial lesions and 10 cervical lesions) in which 70% of endometrial malignant lesions were hypointense on T2-weighted images and 30% were heterogeneous.

In our study, heterogeneous post contrast enhancement was seen in 8 (66.7%) lesions, and homogeneous post contrast enhancement was seen in 4(33.3%) lesions; in line with **Elsammak et al. [17]** who found from the examined 16 endometrial carcinomas, 6 lesions showed intermediate enhancement and 10 cases showed heterogeneous post contrast enhancement.

In the current study from whole 12 malignant endometrial tumors, we found that 10 lesions were restricted in both DWI and DWIBS with 2 false negative results, proven to be well differentiated endometroid adenocarcinoma by histopathology, which were of heterogeneous SI at T2WI with heterogeneous post contrast enhancement. This agrees with **Mori et al. [19]** who compared between signal intensities of different histopathological types of the endometrial cancer and found that heterogeneous signal on diffusion-weighted images were more frequent in serous carcinoma than in endometroid carcinomas (61% vs. 32%)

($p < 0.05$), respectively. This may be explained by low cellularity in endometriod carcinoma which leads false negative results in DWI and ADC. In our study there was significant difference between standard MRI and histopathology in detecting tumor staging at stages I and II, $p<0.05$, while DWIBS could accurately detect tumor extension compared to the histopathological results with no significant difference $p>0.05$. So DWIBS shows helpful role in loco-regional staging of the endometrial cancer and their extension, especially in early staging, with accurate assessment of degree of myometrial invasion secondary to the consipicousity of the restricted endometrial tumor signal in comparison to the suppressed background signal intensity.

Limitations:

Small sample size with defective different gynecological pathologies with non-characterization of their pattern by DWIBS as (uterine sarcoma, endometrial polyps, cervical polyps, vaginal and perineal masses).

CONCLUSIONS

DWIBS can aid and boost MRI's confidence in identifying or ruling out possible malignancy in gynecological malignancies. DWIBS is very useful in diagnosis of borderline ovarian tumors being not restricted in comparison to false restriction on DWI in standard MRI protocol, thus permitting better management to maintain fertility. Regarding cervical tumors, it has a great role if fertility preserving surgery is planned and for radiotherapy planning and administration with early detection of small lesions by increasing the signal restriction in contrast to the suppressed background and accurate diagnosis of its extension and staging. Regarding endometrial cancer, it shows great significant correlation with the histopathological staging of tumor and its extension with accurate evaluation of myometrial invasion in comparison to the conventional MRI.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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