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RESEARCH

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Role of multi-parametric magnetic resonance imaging in preoperative staging of cervical carcinoma in females

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Abstract

Background In cervical cancer, accurate diagnosis of parametrial invasion (PMI) helps in determining the next step in management, either surgical resection or neoadjuvant therapy. Cervical cancer staging is still determined according to the clinical findings. But it is widely recognized that there are differences between clinical evaluation and the actual disease extent, particularly for PMI. In this prospective study, we investigate the relationship between clinical staging and magnetic resonance imaging (MRI) staging with post-management findings among patients with cervical cancer who underwent pre-treatment MRI, using fused T2-weighted image/diffusion-weighted imaging (T2/DWI).

Results Based on examination under anesthesia (EUA), 80% of patients showed PMI, while fused T2/DWI was positive for PMI in 77.5% of patients. In all analyzed cases (40 females), MRI had sensitivity, specificity, and accuracy of 91%, 75%, and 87.5% compared to EUA. In the operated patients (24 females), MRI likewise had sensitivity, specificity, and accuracy of 81.3%, 87.5%, and 83%, respectively. In comparison with the postoperative results, the EUA showed higher sensitivity and accuracy than MRI (92.9% vs. 81.3%) and (83.3% vs. 79.2%), respectively, in the detection of PMI in operated cases. However, MRI was more specific in the PMI detection in cases with cervical cancer than EUA (75% vs. 70%).

Conclusion MRI (with the aid of fused T2/DWI) improves the diagnostic performance for the PMI assessment in cases with cervical carcinoma. Therefore, MRI is helpful in choosing surgical candidates.

Keywords Uterine cervical neoplasms, Preoperative care, Magnetic resonance imaging, Neoplasm staging, Image interpretation, Early detection, Cervical carcinoma, Fused T2/DWI, Gynecological oncology, Parametrium

Background

Squamous cervical carcinoma (SCC) is the fourth most common cause of cancer-related mortality for women worldwide, which accounts for 75–80% of cases [1]. Cervical cancer is still staged based on clinical findings [2]. It is widely recognized that there are differences between the clinical examination and the actual disease extent, particularly in cases with parametrial infiltration (PMI) [3]. For this reason, MRI-based imaging techniques have been suggested for evaluating PMI [4]. More information is required on the efficacy of MRI and clinical examination to detect parametrial cancer spread because PMI is a known factor influencing treatment choices and prognosis [5].

A conserved hypointense stromal rim is a unique result for the exclusion of parametrial invasion on T2WI, which is often used to assess parametrial invasion. However, if the tumor is big enough to damage the cervical stromal

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ring, it could be challenging to tell whether or not parametrial invasion is present [6]. Due to the tumor's increased signal intensity and lower apparent diffusion coefficient value compared to healthy cervical tissue, diffusion-weighted imaging (DWI) offers the ability to determine the cervical cancer's real extent. However, due to its inadequate anatomical details and low spatial resolution, DWI may have limitations for the precise assessment of parametrial invasion. These restrictions might be removed by combining T2WI with DWI, which could give information on the tumor's anatomical and functional characteristics [7].

Therefore, in this study, we tried to understand the MRI role in preoperative cervical cancer staging, as well as the value of fused T2/DWI images to enhance PMI detection.

Methods

This cross-sectional observational study was carried out at our University hospital to evaluate the role of MRI in preoperative staging of cancer cervix with special emphasis upon the fused T2/DWI to identify the extent of parametrial involvement. The study included 40 patients with pathologically proven cervical cancer who required further MRI for preoperative staging.

Sampling method

Consecutive sampling according to inclusion and exclusion criteria, within a duration of 24 months, since obtaining the necessary approvals to proceed with the data collection and analysis (September 1, 2021–August 31, 2023).

Inclusion criteria

- Female patients.
- Patients with pathologically proven cervical carcinoma.

Exclusion criteria

- Obese patients (more than 120 kg).
- Patients with benign cervical lesions (cervical polyps, fibroids, … etc.).
- Previous pelvic surgery for other gynecological reasons.
- Previously managed cervical carcinoma (surgical "i.e., stump carcinoma" or by neoadjuvant treatment)

Also, we ruled out any patients who were absolutely contraindicated for MRI, such as patients with pacemakers and metallic hip arthroplasty, as well as claustrophobic patients (if not suitable for MRI examination with sedation).

Sample size

By setting the confidence level at 95% and the margin of error to + 0.15 and using the PASS 11 program to calculate the sample size, a sample size of at least 40 female patients with pathologically confirmed cervical malignancy was sufficient to meet the study's objectives after reviewing the findings of earlier studies by Knoth et al. [8], which revealed that the difference between MRI and clinical staging was observed in (27.2%) of patients with newly biopsy-proven cervical cancer.

Study procedures

After taking a full medical and gynecological history, a thorough clinical examination by referring gynecologists was conducted on all patients. Ultrasound examination was carried out as screening, to confirm the presence of cervical lesions, before referring the patients to our department. All patients were examined under anesthesia (EUA) at the gynecology clinic. In patients who underwent surgery, postoperative histopathology was done.

MRI examination

The study was performed with 1.5 Tesla (Avanto-Siemens) and (Ingenia-Philips) MR systems using an abdominal coil. The patients were supine with a body-phased array surface coil covering the mid-symphysis pubis to renal hilum. The average duration of the examination ranged from 20 to 25 min.

MRI protocol

- Localizing sequences in all planes.
- Turbo spin echo (TSE) T2-W sequences in the axial and sagittal planes without fat saturation.
- Images with axial T1 weighting.
- Axial and sagittal T2-WI with fat suppression.
- DWI with ADC mapping (b 0–500–1000).
- Susceptibility weighted imaging (SWI) and phase encoding sequences.
- Angulated images are crucial for the accurate representation of the cervical stromal ring (axial planes) and for assessing how the cervix connects with surrounding tissues as follows:
  - The endocervical canal's long axis is parallel to the coronal planes.
- For further suspected infiltration of the uterus or vagina, angulated pictures perpendicular to these structures are taken.

- Fused T2-DWI images to confirm or exclude PMI were conducted on a dedicated workstation for post-processing.

Image analysis and interpretation

MRI was reported in consensus between two experienced radiologists (10 years of expertise and 5 years of experience, respectively, in pelvic imaging) depending on:

(a) Location of tumor, volume, signal intensity, diffusion characteristics.
(b) Stromal invasion depth.
(c) Lower uterine segment involved extension (if present).
(d) Parametrial invasion.
(e) Loco-regional lymph nodes.

Interpretation of these results, with correlation to clinical staging and post-management findings and pathology results took place.

Statistical analysis

The IBM SPSS software package, version 20.0, is used to analyze the obtained data and represent it in the form of tables and graphs. Numbers and percentages were used to represent qualitative data. Measures including range, mean, standard deviation, median, and interquartile range were used for expressing the quantitative data. To evaluate the effectiveness of various diagnostic modalities, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy were determined.

Results

In the literature, PMI detection by MRI has been reported to have a wide range of diagnostic accuracy [7, 9]. In the present work, based on EUA, 80% of patients showed PMI, while fused T2/DWI was positive for PMI in 77.5% of patients. Among all studied cases (40 females), the MRI diagnostic accuracy compared to that of EUA revealed that MRI's sensitivity, specificity, and accuracy of 91%, 75%, and 87.5%, respectively, and also, MRI's sensitivity, specificity, and accuracy in the operated cases (24 females) were 81.3%, 87.5%, and 83%, respectively. In comparison with the postoperative results, we found that the EUA showed higher sensitivity and accuracy than MRI (92.9% vs. 81.3%) and (83.3% vs. 79.2%), respectively, in the detection of PMI in operated cases. However, MRI was more specific in the detection of PMI in cervical cancer cases than EUA (75% vs. 70%). Our findings suggest that MRI is relatively comparable to EUA in detecting PMI in cervical cancer patients.

Ages of the patients varied from 31 to 85 years, with a mean age ± standard deviation of 55.1 ± 13.9 years. The most frequent complaints were dysfunctional uterine bleeding (DUB) in 77.5% of patients, offensive discharge in 32.5% of patients, cervical mass in 22.5% of patients, pelvic heaviness in 10% of patients, urine incontinence in 10%, and pelvic pain in 7.5% of patients (Tables 1, 2).

Squamous cell carcinoma represented 58% of all cervical malignancies as the most prevalent pathological entity of cervical tumors that was examined in our study (Table 3).

Concerning the MRI findings, the T2WI signal was intermediate in more than half of our cases. DWI was restricted in all lesions. ADC ranged between 0.6 and

Table 1 The distribution of cases according to age

Age	
Min.–Max	31–85 years
Mean ± SD	55.1 ± 13.9
Median (IQR)	54.0 (42.75–65.0)

Table 2 The distribution of cases according to clinical presentation

Clinical presentation	*N* (%)
DUB	31 (77.5%)
Offensive discharge	13 (32.5%)
Cervical mass	9 (22.5%)
Pelvic heaviness	4 (10.0%)
Urine incontinence	4 (10.0%)
Pelvic pain	3 (7.5%)
Menorrhagia	2 (5.0%)
Post-coital bleeding	2 (5.0%)
Hematuria	2 (5.0%)
Dysmenorrhea	2 (5.0%)
Anemia	1 (2.5%)
Sciatic pain	1 (2.5%)
Pelvic adhesions	2 (5%)

Table 3 The distribution of cases according to preoperative biopsy

Preoperative Biopsy	*N* (%)
Squamous cell carcinoma	24 (58.0%)
Adenocarcinoma	7 (17.5%)
Small cell carcinoma	3 (7.5%)
Adenosquamous carcinoma	2 (5.0%)
Clear cell carcinoma	2 (5.0%)
Sarcoma (NOS)	2 (5.0%)

0.9 with a mean ± SD of 0.81 ± 0.1. Only seven of the patients received contrast (17.5%), heterogeneous enhancement was seen in 7.5% of the lesions, homogeneous enhancement in 5%, and hypo-enhancement in 5% of cases (Table 4).

Based on MRI, vaginal invasion was detected in 29 patients (72.5%), mostly (48.3%) within the upper third. rectal invasion only in 12.5% of our patients while lower uterine segment invasion in 67.5% of our cases. The incidence of lymph node metastases was high (72.5% had positive nodal metastasis), the majority were pelvic lymph nodes, while only 10.3% were bilateral pelvic and para-aortic regions (Table 5).

The distribution of FIGO 2018 classification in studied lesions showed that the most common FIGO-class were IV-A (30%), followed by III-C 1 (25%), then II-B came third (17.5%), III-C (10%), and lastly III-C2 (in 5%) (Table 6). Among 40 patients, 24 patients (60%) underwent surgical intervention, while 16 patients (40%) underwent neoadjuvant chemotherapy and continued to follow-up by MRI.

Based on EUA, 80% of patients showed PMI, while fused T2/DWI was positive for PMI in 77.5% of patients.

Table 4 The distribution of examined lesions based on MRI characteristics

T2WI	
heterogeneous hyperintense	8 (20.0%)
heterogeneous intermediate	3 (7.5%)
Hyperintense	3 (7.5%)
Hypointense	2 (5.0%)
Intermediate	22 (55.0%)
intermediate with cystic changes	1 (2.5%)
Isointense	4 (10.0%)
DWI	
Restricted	40 (100.0%)
ADC × 10^3	
Min.–Max	0.6–0.9
Mean ± SD	0.81 ± 0.1
Median (IQR)	0.8 (0.78–0.9)
Fused T2/DWI	
Negative	9 (22.5%)
Positive	31 (77.5%)
SWI	
Blooming	18 (45.0%)
No blooming	22 (55.0%)
Contrast	
Heterogeneous enhancement	3 (7.5%)
Homogenous enhancement	2 (5.0%)
Hypo enhancing	2 (5.0%)
No contrast	33 (82.5%)

Among all studied cases (40 lesions), the MRI diagnostic accuracy compared to EUA showed that according to Table 7, the sensitivity, specificity, and accuracy of MRI are 91%, 75%, and 87.5%, respectively. In the operated cases (24 lesions), MRI's sensitivity, specificity, and accuracy are 81.3%, 87.5%, and 83%, respectively (Table 8).

Comparing the postoperative results, we found that the EUA showed higher sensitivity and accuracy than MRI (92.9% vs. 81.3%) and (83.3% vs. 79.2%), respectively, in the detection of PMI. However, MRI was more specific in the detection of PMI in cervical cancer cases than EUA (75% vs. 70%) (Table 9).

Discussion

Parametrial invasion plays a crucial role in both clinical staging and the therapeutic strategy shunting point. The decision of which patients should get chemo-radiation treatment must be made based on an accurate PMI assessment [10]. In order to enhance local control and survival if PMI is discovered after surgery, further chemo-radiation is recommended, although this is linked to increased morbidity and expense [11].

In this prospective study, we investigated the relationship between clinical staging and magnetic resonance imaging (MRI) staging with post-management findings among patients with cervical cancer who underwent pretreatment MRI, using fused T2-weighted image/diffusion-weighted imaging (T2/DWI).

The majority of earlier investigations agree with our findings. Our findings corroborate the findings of Bourgioti et al. [12] prospective analysis of 115 cervical cancer patients, indicated that MRI was more accurate than clinical evaluation for PMI (tumor estimation). They came to the conclusion that included MRI in the clinical assessment improved the precision in identifying PMI. MRI has a 73.33% sensitivity and a 92.5% specificity, respectively. When compared to surgical pathology, Yang et al.'s findings [13] found that MRI had a 77.2% accuracy rate for diagnosing PMI, a 53.8% sensitivity rate, and an 82.1% specificity rate. Also, additionally, in Shweel et al.'s study [14] MRI had a specificity of 85.7% and was extremely sensitive (100%) in identifying parametrial invasion. With an accuracy rate of 90.9% versus 79.0%, a different research by Kraljevic et al. [15] demonstrated that MRI was superior to clinical examination for cervical cancer staging.

Another factor attributes to that is relatively large sizes of tumor at the time of initial diagnosis, hindering the results of EUA and MRI relatively comparable. The preoperative cervical cancer staging may also benefit from using MRI, which is a reliable, repeatable, and non-radiating imaging approach. Our work suggests that MRI might be used as a practical, noninvasive,

Table 5 Tumor extension to the nearby organs in studied lesions (Represented cases are attached in Additional file 1)

PM invasion	
Negative	9 (22.5%)
Positive	31 (77.5%)
Vaginal invasion	
Negative	11 (27.5%)
Positive	29 (72.5%)
Positive vaginal invasion: (*n* = 29)	
Positive upper 2/3	7 (24.1%)
Positive upper 1/3	14 (48.3%)
Positive lower 1/3	2 (6.9%)
Rectal invasion	
Negative	35 (87.5%)
Positive	5 (12.5%)
Lower Uterine segment	
Negative	13 (32.5%)
Positive	27 (67.5%)
Urinary Bladder invasion	
Negative	24 (60.0%)
Positive	16 (40.0%)
Hydronephrosis	
Bilateral	5 (12.5%)
Left	4 (10.0%)
Right	2 (5.0%)
None	29 (72.5%)
Side Wall Pelvic invasion	
Negative	36 (90.0%)
Positive	4 (10.0%)
Lymph nodes	
Negative	11 (27.5%)
Positive	29 (72.5%)
Positive nodes: (*n* = 29)	
Bilateral pelvic	16 (55.2%)
Unilateral pelvic	10 (34.5%)
Bilateral pelvic and para-aortic regions	3 (10.3%)

Table 6 The distribution of studied cases according to FIGO 2018 classification

FIGO.2018	
IB-1	2 (5%)
IB-2	1 (2.5%)
II-B	7 (17.5%)
IIA-2	1 (2.5%)
IIIC 1	14 (35.0%)
IIIC 2	2 (5.0%)
IVA	12 (30.0%)
IVB	1 (2.5%)

and accurate preoperative staging technique of cervical cancer in routine clinical practice. Additionally, our work shows the diagnostic value and applicability of combined T2/DWI in suspicious PMI prediction in cervical cancer patients.

In contrast to our findings, Zhang et al. [16] reported that the PMI AUC using MRI was only 0.56, and the sensitivity was 16.7%. However, they provided an explanation for this disappointing performance, stating that pelvic inspection had previously eliminated parametrial infiltration from the research cohort. In this investigation, PMI was therefore likely early or even micro-infiltration, which is less likely to be detected by MRI. Additionally, Roh et al. [17] recommended that

Table 7 Comparison of diagnostic efficacy of MRI to EUA for PM invasion in all lesions

		EUA				Sensitivity	Specificity	PPV	NPV	Accuracy	*P*-value
		Positive (*n* = 32)		Negative(n = 8)							
		No	%	No	%						
Total sample (*n* = 40)	MRI Positive	29	72.5%	2	5.0%	91%	75%	94%	67%	87.5%	**0.0005***
	Negative	3	7.5%	6	15.0%						

Table 8 Diagnostic accuracy of MRI for PMI compared to EUA in operated cases

		EUA				Sensitivity	Specificity	PPV	NPV	Accuracy	P-value
		Positive (*n* = 16)		Negative (*n* = 8)							
		No	%	No	%						
Total sample (*n* = 24)	MRI Positive	13	72.5%	1	5.0%	81.3%	87.5%	93%	70%	83%	**0.002***
	Negative	3	7.5%	7	15.0%						

Table 9 Diagnostic accuracy of EUA for PMI in operated cases

		Postoperative result				Sensitivity	Specificity	PPV	NPV	Accuracy	*P*-value
		Positive (n = 16)		Negative (n = 8)							
		No	%	No	%						
Total sample (*n* = 24)	EUA										
	Positive	13	54.2%	3	12.5%						
	Negative	1	4.2%	7	29.2%	92.9%	70%	81.3%	87.5%	83.3%	**0.002***

preoperative decision-making for early cervical cancer patients based on MRI diagnosis should be carefully evaluated, especially in light of known variables promoting misdiagnosis. Remarkably, the prevalence of PMI revealed by MRI varies significantly; it was 25% in the study by Park et al. [7] and 12% in the study by Mongula et al. [18] compared to 77.5% in the current study. The selection criteria for patients may be one factor in this discrepancy.

In this study, the accuracy, sensitivity and specificity for MRI in defining PMI were comparable to EUA, and this is attributed to the fact that most of the lesions included in the study were stage FIGO III-C 1 and higher, and after careful revision of few cases below III-C-1, it was found that MRI is more sensitive and specific than EUA for PMI diagnosis (correlated with postoperative histopathology). The number of those cases unfortunately is not enough to generate results that are statistically significant.

The wide range of PMI detection points to the advanced tools and reading skills needed to determine this parameter. The usefulness of an MRI as a diagnostic tool may depend on a number of variables, involving the MRI device itself, the used protocol of scanning, and the radiologists' training level. Woo et al. [19] indicates that the combination of both 3-T scanners with DWI may improve diagnostic performance. DWI is capable of conducting functional water mobility analyses, tissue cellularity, and cellular membrane integrity. Combining DWI and T2WI can improve diagnostic performance in detecting PMI [7]. Those that employed DWI had greater pooled sensitivity and specificity than those that did not (82% vs. 72% for sensitivity and 97% vs. 91% for specificity; $P < 0.010$) [19]. Also, Mongula et al. [18] found that fusing T2WI with DWI improved diagnostic performance, particularly by lowering false-positive results, for the measurement of PMI in cervical cancer patients. The performance improvement may be attributed to a more precise cervical cancer delineation using fusion T2W/DWI, which enables better differentiation between

tumor, pressure-induced alterations, edema, and/or the biological response of the surrounding cervical tissue.

Recent research by Sodeikat et al. [5] examined the precision of parametrial assessment in cervical cancer patients utilizing MRI and clinical examination under general anesthesia. As a unique idea to enhance cervical cancer staging, they developed aEUA, or clinical examination while under general anesthesia enhanced by the showing of MR images in the operation room. They discovered that compared to MRI alone, EUA offers superior accuracy, sensitivity, and specificity as well as better negative and positive predictive values.

The relatively small sample size is a major limitation of this work. Therefore, our findings must be interpreted with caution. Because radiation, chemotherapy, or both have been known to affect MRI features and histopathologic outcomes by killing tumor cells, we excluded patients with incomplete clinical/pathological data and patients with cervical cancer who had received prior or concurrent treatment (radiation, chemotherapy, or both). This resulted in a smaller sample size. Also, as we lack the concept of screening for cervical cancer among the studied population, most of the lesions included in the study were relatively in advanced stages (II-A2 and above), with lesions more than 4 cm in dimensions, hindering the detection of PMI either with MRI or EUA comparable.

Conclusion

The best noninvasive approach for preoperative assessment of females with suspected cervical cancer is MRI, which is useful for accurately assessing the PMI as well as detecting and characterizing the tumor itself, allowing for more exact staging of tumor and planning of treatment. The relatively new post-processing method of merging T2WI and DWI can simultaneously give anatomical and functional insights regarding cervical cancers and its true extent. Combining T2WI and DWI improves the diagnostic performance of MRI for the assessment of parametrial invasion in cervical cancer. MRI is therefore useful in selecting which patients will require surgery.

Abbreviations

ADC	Apparent diffusion coefficient
EUA	Examination under anesthesia
DWI	Diffusion-weighted imaging
MRI	Magnetic resonance imaging
NPV	Negative predictive value
PMI	Parametrial invasion
PPV	Positive predictive value
T2WI	T2-weighted image
SCC	Squamous cervical cancer

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43055-024-01222-1.

Additional file 1. Case Presentation.

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Author contributions

HH analyzed and interpreted the patient clinical and radiological data for cervical cancer staging. AI reviewed all surgical data. HH, AS, SA, and AA were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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Availability of data materials

Upon reasonable request, the corresponding author will provide access to the datasets used and/or analyzed during the current work.

Declarations

Ethical approval and participate acceptance consent

Official permission was obtained from the Radiodiagnosis Department, Faculty of Medicine, Ain Shams University. The scientific ethical committee considerations were respected. As part of the history-taking process, the study group was informed of the nature and objective of the investigation.

Consent for publication

Not applicable.

Competing interests

The authors claim to have no conflicts of interest.

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