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Evaluation of multi-parameter MRI in preoperative staging of endometrial carcinoma

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ABSTRACT

Background: Endometrial carcinoma (EC) is a prevalent gynecological malignancy, necessitating accurate preoperative staging for effective treatment planning. This study explores the application value of multi-parameter MRI in diagnosing and staging endometrial cancer.

Methods: Seventy-six patients diagnosed with endometrial cancer underwent 3.0 T pelvic MRI within two weeks before surgery. Imaging data were analyzed based on FIGO clinical staging criteria. The study assessed the sensitivity, specificity, positive predictive value, and negative predictive value of MRI for each stage.

Results: Postoperative pathology confirmed 71 cases of endometrial adenocarcinoma, 3 serous adenocarcinoma, and 2 clear cell carcinomas. MRI staging showed a high consistency (Kappa value = 0.786) with postoperative pathology. The overall accuracy of MRI diagnosis was 86.8%. Sensitivity and specificity varied for each stage: IA (91.3%, 96.2%), IB (88.6%, 93.8%), II (97.4%, 89.2%), and III (84.2%, 100%).

Conclusion: While there was a slight misdiagnosis rate, the overall accuracy of preoperative MRI for endometrial cancer was high, aiding in precise diagnosis and clinical staging. MRI effectively identified myometrial infiltration, cervical involvement, paracentral extension, and lymph node metastasis. Further research with larger sample sizes is recommended for enhanced reliability.

1. Introduction

Endometrial carcinoma (EC) is one of the most common malignant tumors of the female reproductive system and the most common gynecological malignant tumor in developed countries [1,2]. According to the latest statistics in the United States in 2017, there were about 61380 new cases of endometrial carcinoma in China. The mortality rate is as high as 17.8%, ranking sixth in the death rate of female malignant tumors [2,3]. In our country, due to the improvement of economic level and people's living standards, dietary structure, and the changes of environment, the incidence of endometrial cancer also increases year by year, second only to cervical cancer at present, the new cases of endometrial cancer are about 200,000 per year, the death cases of endometrial cancer are also rising year by year [3]. At present, the exact cause of endometrial cancer is not clear, but it has been reported that the risk factors for endometrial cancer include obesity, excessive estrogen intake, early menarche, late menopause, tamoxifen use, infertility and so on[4,5]. The most common clinical symptom of endometrial cancer is abnormal uterine bleeding, which can occur before and after menopause, especially after menopause. The most common pathological type of endometrial carcinoma is endometrioid adenocarcinoma, which can be divided into highly differentiated (grade), moderately differentiated (grade II) and poorly differentiated (grade III) in terms of pathological differentiation [5,6]. There are significant differences in surgical resection methods and prognosis among different grades of endometrioid adenocarcinoma. The higher the degree of differentiation, the better the prognosis, and the worse the prognosis [6].

Segmental curettage is the gold standard for clinical diagnosis of endometrial cancer, and can also determine the pathological type of endometrial cancer before surgery. However, segmental scraping is invasive and blind, which is easy to miss small lesions or lesions located in the horn of the palace, and can not accurately indicate the scope and depth of tumor involvement [7,8]. Due to the small number of pathological samples obtained by curettage, the results obtained by curettage to evaluate the pathological grade of the whole lesion are error-prone and often lower than the histological grade judged after surgery [8]. Therefore, it is very meaningful and necessary to select appropriate imaging examinations for accurate preoperative staging of patients with

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endometrial cancer, which can also provide an important basis for clinicians to choose treatment plans and further prognosis assessment [8,9]. Preoperative imaging for endometrial cancer includes abdominal or vaginal ultrasound, CT, PET/CT, and MRI. B-ultrasound has the advantages of no radiation harm, affordable cost, simple operation and short inspection time, and can observe patients from multiple approaches and angles, which can be used as the preferred method for diagnosing most gynecological diseases. However, B-ultrasound has the disadvantages of poor soft tissue resolution, easy misdiagnosis of early endometrial cancer, and poor judgment of myometrial invasion and tumor metastasis [8–10]. CT imaging speed is fast, and the display of lesions, lymph nodes and distant metastases can be better evaluated. Compared with MRI, CT has no advantage in preoperative staging in judging the extent of endometrial cancer involving muscle layer and cervix, but CT has radiation hazards and has a certain impact on the health of patients [10,11]. At present, there are few reports on PET/CT's role in the preoperative staging of endometrial cancer. The advantage of PET/CT is that it can integrate the anatomic image of the tumor with the functional image, and it can detect not only lymph node metastasis of endometrial cancer but also distant metastatic lesions, and it is more sensitive to lymph node metastasis than other examination methods. However, the cost of PET/CT examination is relatively high for patients, and each examination requires the use of a certain amount of radiopharmaceutics, which has certain radiation hazards to patients [12,13]. Therefore, the clinical application of PET/CT in endometrial cancer is not widely used before surgery. MRI not only has high soft tissue resolution, spatial resolution and tissue contrast, but also can be used for multi-dimensional, multi-directional and multi-parameter imaging. It is superior to ultrasound and CT in preoperative diagnosis of myographic invasion and lymph node metastasis of endometrial cancer, and does not produce ionizing radiation, so it is the best imaging method for endometrial cancer [14,15]. Endometrial carcinoma (EC) poses a significant health burden, with rising incidence and mortality rates. This study addresses the critical need for accurate preoptostaging in EC and focuses on evaluating the utility of multi-parameter MRI for diagnosis. By assessing the imaging accuracy in identifying key pathological features, such as myometrial infiltration and lymph node metastasis, the research aims to fill existing knowledge gaps and contribute to improved clinical decision-making for patients with endometrial cancer.

2. Materials and methods

2.1. General data

A total of 76 patients diagnosed with endometrial cancer in our hospital from October 2020 to October 2022, aged 32–75 years, with an average age of 53.21±7.64 years, were selected and collected. Inclusion criteria: ① Patients who underwent surgery and pathological stage in our hospital for the first time; ② Patients who did not receive preoperative radiotherapy or chemotherapy; ③ There were complete clinical and pathological data. Although tumor reduction is feasible in principle for patients with stage IV endometrial cancer, this study excluded patients with stage IV endometrial cancer because clinicians and patients with distant metastasis almost gave up surgery and adopted other treatment methods. The main symptoms of the patients were irregular vaginal bleeding after menopause, and some patients found abnormal uterine bleeding before menopause. Gynecologists with the title of attending or above conducted the examination to determine whether to perform the operation and the postoperative pathological staging. The operation-pathological staging was conducted in strict accordance with the standards of FIGO clinical staging (2014), and 3.0 T pelvic MRI examination was performed in all patients eligible for surgery within 2 weeks before the operation.

Table 1
International Association of Obstetrics and Gynecology 2014 (FIGO) installment.

Stage	pathological feature
I	The tumor is confined to the body of the uterus
IA	No or less than 1/2 myographic immersion
IB	More than 1/2 myographic immersion
II	The tumor involved the cervical stroma and did not extend beyond the uterine body
III	Local/regional spread of the tumor
IIIA	The tumor involves the serous membrane of the uterus and/or the adnexa
IIIB	Vaginal and/or paracentral involvement
IIIC	Pelvic and/or paraaortic lymph node metastases
IV	Tumor invasion of the bladder and/or rectal mucosa metastases, and/or distant metastases occur
IVA	Tumor invasion of the bladder and/or rectal mucosa metastases
IVB	Distant metastasis, including intraperitoneal metastasis and/or inguinal lymph node metastasis

2.2. Inclusion and exclusion criteria

Patients diagnosed with endometrial cancer and scheduled for surgery at our hospital between October 2020 and October 2022 were included. Inclusion criteria comprised first-time surgical cases with complete clinical and pathological data, excluding those who underwent preoperative radiotherapy or chemotherapy. Patients with distant metastasis (Stage IV) were excluded due to the rarity of surgical intervention in such cases. The study aimed to ensure a homogeneous sample for accurate evaluation of the MRI's diagnostic and staging capabilities.

2.3. MRI scanning protocol

A 3.0 T Philips Achieva double gradient superconducting magnetic resonance instrument was employed, utilizing an 8-channel phased array surface coil. The imaging sequences included T1-weighted imaging (T1WI) with fast spin echo (TSE) sequence, TSE T2-weighted imaging (T2WI) sequences in axial, coronal, and sagittal planes, axial fat-suppressed T2WI sequence, and dynamic contrast-enhanced (DCE) imaging. Diffusion-weighted imaging (DWI) was conducted using a single excitation fast spin Echo Planar Imaging (SE-EPI) sequence. Gadolinium-based contrast agent (Gd-DTPA) was administered with a special high-pressure magnetic resonance syringe.

2.4. Scanning method

Ensure that all subjects do not have absolute contraindications to MRI. Explain the precautions of MRI examination to the patient in advance. Have the patient exhaust the intestinal contents as much as possible before examination to reduce image artifacts. The MRI examination sequences include: routine scan sequence: T1WI cross-sectional axial scan with fast spin echo (TSE) sequence; TSE T2WI sequences of axial, coronal and sagittal bits scanning, and T2WI sequence sagittal, axial fat suppression scanning. DWI uses a single excitation fast spin Echo Planar Imaging (SE-EPI) sequence cross-section. Then dynamic enhanced scanning was performed in axial, coronal and sagittal positions.

2.5. Preoperative diagnosis with MRI images

Two imaging attending physicians independently read MRI images and make preoperative diagnosis according to the new staging criteria for endometrial cancer published by FIGO in 2014 (Table 1).

2.6. Preoperative staging based on MRI images

Two imaging attending physicians independently evaluated the MRI images according to the 2014 FIGO clinical staging criteria for

Table 2
Complete pathological data of 76 patients with endometrial carcinoma.

Index	Cases
Pathological pattern	
Endometrioid adenocarcinoma	71
Serous adenocarcinoma	3
Clear cell type	2
Differentiated degree	
High differentiation	18
Moderate differentiation	40
Low differentiation	18
Operation-Pathological staging	
IA	50
IB	9
II	10
III	7
Combined with uterine fibroids	14
Combined with adenomyosis of uterus	4

endometrial cancer. The staging criteria included IA (confined to endometrium), IB (invasion beyond the endometrial-myometrial junction), II (cervical involvement), and III (local/regional spread involving serous membrane, adnexa, vaginal/paracentral areas, and pelvic/para-aortic lymph nodes). Discrepancies in diagnosis were resolved through consensus, and the final diagnosis was compared with the postoperative pathological staging results. Staging accuracy and consistency were assessed through statistical analysis.

IA: If the lesion was confined to the endometrium, the low signal of the junction zone on T2WI was complete and uninterrupted, the enhancement zone under the intima was smooth and complete on DCE, and the lesion showed high signal on DWI. Or the lesions with medium signal on T2WI break through the binding zone, causing the low signal of the binding zone to appear localized or diffuse loss or interruption. The heterogeneous enhanced mass on DCE is more obvious than that near the normal enhanced muscle layer; while the subintimal enhancement zone is destroyed, locally interrupted or indistinct, and the lesions on DWI show obvious high signal. The depth of lesion infiltration was $< 1/2$ muscle layer.

IB: The medium signal tumor invaded the outer layer of the muscle, and the depth of infiltration was $> 1/2$ of the muscle layer.

II: The mass with moderate signals extends down to the cervix and dilates the cervical canal.

III: A medium signal mass may cause discontinuity and local interruption of low signals in the serous layer of the uterus, or involvement of the paruterine, vaginal fornix, or nodule signals may be seen on the fallopian tubes and ovaries. Lymph node metastasis is generally characterized by unclear boundary of lymph node skin and medulla, shape from oval to round, and its short diameter > 10 mm.

2.7. Surgical pathologic diagnosis

The complete pathological data of the patients were analyzed by gynecological doctors with titles above the attending position, and the judgment was made according to the new staging criteria of FIGO 2014 EC.

2.8. Statistical analysis

All data were statistically analyzed using IRM SPSS Statistics Version 22.0 software package. The measurement data were expressed by mean ± standard deviation (X±S), and the diagnostic results of postoperative pathology were set as the "gold standard". The sensitivity, specificity, negative predictive value and positive predictive value of 3.0 T MRI for each stage of endometrial cancer were calculated by Chi-square analysis of paired four-cell table data, and the results were expressed by percentage (%), and the consistency of Kappa value between this method and postoperative pathological stage was detected.

Table 3
Comparison of preoperative MRI staging and pathological staging.

MRI staging	Pathological staging				Total
	IA	IB	II	III	
IA	47	2	1	0	50
IB	2	7	2	0	11
II	1	0	7	2	10
III	0	0	0	5	5
Total	50	9	10	7	76

Table 4
Preoperative staging of MRI diagnostic test evaluation index.

MRI staging	Sensibility	Specificity	Positive predictive value	Negative predictive value
IA	91.30%	96.20%	98.10%	82.60%
IB	88.60%	93.80%	63.40%	97.80%
II	97.40%	89.20%	95.40%	73.40%
III	84.20%	100%	100%	91.80%

3. Results

3.1. Postoperative pathology

76 patients with EC surgical pathology pathologic types (see Table 2) confirmed 71 cases of endometrial adenocarcinoma, 3 cases of serous adenocarcinoma, 2 cases of clear cell carcinoma. There were 18 cases with high differentiation, 40 cases with moderate differentiation and 18 cases with low differentiation. Pathological stages (stage A 50 cases, stage B 9 cases, stage II 10 cases, stage III 7 cases, of which 14 cases with uterine fibroids, 4 cases with adenomyosis.

3.2. Comparative analysis of preoperative MRI staging and postoperative pathological staging

Compared with pathology (see Table 3 and Table 4), there were 66 cases with correct MRI staging, and 50 cases with stage IA were diagnosed by preoperative MRI, of which 47 cases were correct staging, 2 cases were Stage IB underestimated as stage IA, and 1 case was stage II underestimated as stage IA. Preoperative MRI diagnosis of 11 cases of stage IB, 7 cases of correct stage, 2 cases stage IA overestimated stage IB, 2 cases of stage II underestimated stage IB. Preoperative MRI diagnosis of 10 cases of stage II, of which 7 cases were correct stage II, 1 case stage IA was overestimated as stage II, 2 cases of stage III was underestimated as stage II. Preoperative MRI diagnosis of stage III in 5 cases, 5 cases were correct stage. Compared with the gold standard of postoperative pathology, the preoperative diagnostic accuracy of MRI was 86.8% (66/76). It is generally believed that Kappa value <0.4 indicates poor consistency, Kappa value between 0.4 and 0.75 indicates general consistency, and Kappa value >0.75 indicates high consistency. In this study, Kappa value was 0.786, indicating that preoperative MRI diagnosis of EC was consistent with postoperative pathology. MRI preoperative diagnosis of endometrial cancer: The sensitivity, specificity, positive predictive value and negative predictive value of stage IA were 91.3%, 96.2%, 98.1% and 82.6%, respectively. The sensitivity, specificity, positive predictive value and negative predictive value of stage IB were 88.6%, 93.8%, 63.4% and 97.8%, respectively. The sensitivity, specificity, positive predictive value and negative predictive value of stage II were 97.4%, 89.2%, 95.4% and 73.4%, respectively. The sensitivity, specificity, positive predictive value and negative predictive value of stage III were 84.2%, 100%, 100% and 91.8%, respectively.

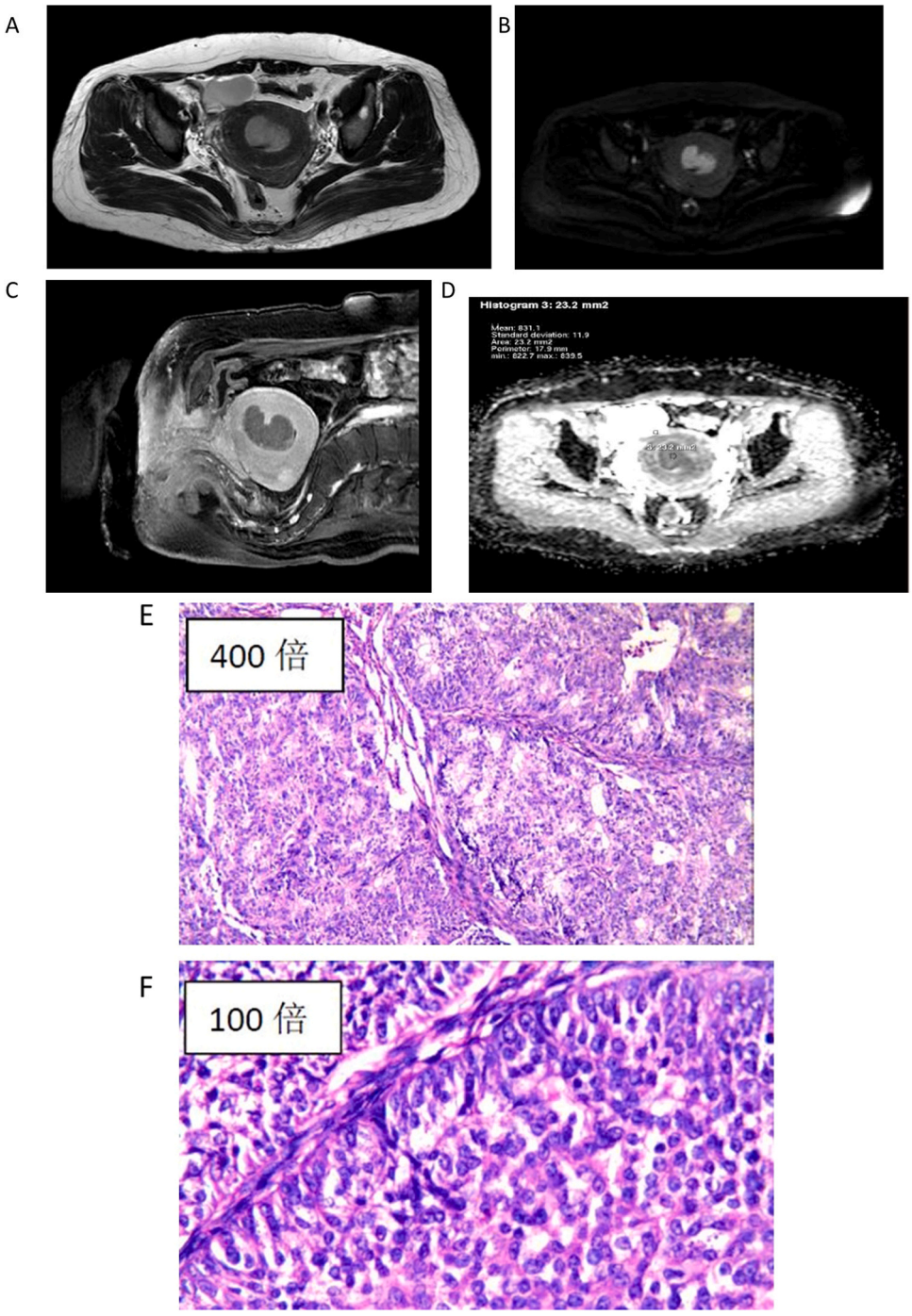

Fig. 1. a-b: Transection a T2WI in visible crumb intrauterine lesions show slightly higher signal, sagittal mild enhanced visible lesions improved significantly lower than that of myometrium, infiltrating muscular layer depth is less than 1/2. Fig. 1c-d: Diffusion weighted imaging (DWI, can b=1000 s/was), the lesion was significantly high signal, ADC is low signal, the average ADC values=0.721×10–3mm2. Fig. 1e-f: Endometrioid adenocarcinoma, superficial muscle invasion (< muscle 1/2), grade II (moderately differentiated), lymph node negative.

4. Discussion

Endometrial cancer is the most common gynecological malignant tumor in western developed countries, ranking fourth among female tumors [15]. In 2015, the consensus meeting of the European Society of Gynecologic Oncology, the European Society of Medical Oncology and the European Society of Radiation Oncology divided EC patients into 6 risk grades according to tumor type, depth of myographic invasion, vascular invasion, cervical interstitial involvement and lymph node metastasis [16,17]. Patients with different risk grades had significant differences in prognosis. The meeting also concluded that EC patients should be treated individually according to their risk level. Some foreign studies believe that lymph node dissection in low-risk EC patients cannot improve the postoperative survival rate of patients, but will increase the risk of surgical complications such as lymphatic cysts and intestinal adhesions [17,18]. Therefore, preoperative staging and risk classification of EC patients will help formulate the most suitable diagnosis and treatment plan for patients, avoiding overtreatment and increasing the economic burden of patients. It can also reduce postoperative complications [18]. Therefore, we need an examination to accurately stage

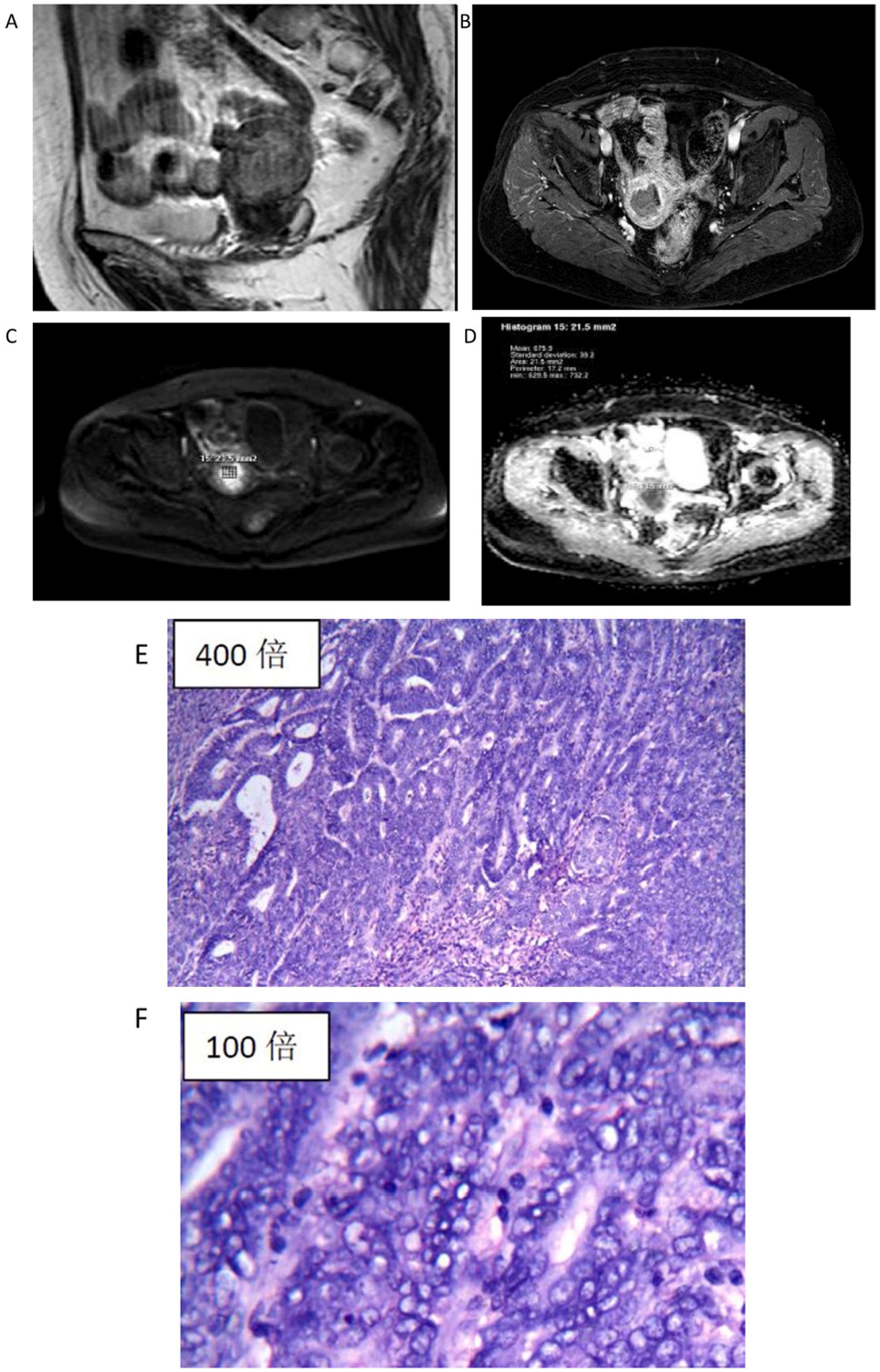

Fig. 2. a-b: Sagittal T2WI lesions has a slightly higher signal, shape is irregular, break through the junction infiltrating muscular layer depth is more than 1/2, cross sectional an enhanced visible lesion slightly improved significantly lower than that of myometrium. Fig. 2c-d: Diffusion-weighted imaging (DWI, b=1000 s/mm2) showed significantly high signal, while ADC showed significantly low signal, with an average ADC value of 0.759×10–3mm2. Fig. 2e-f: Endometrioid adenocarcinoma, deep muscle invasion (> muscle 1/2), grade II (moderately differentiated), lymph node negative.

patients with endometrial cancer before surgery, which not only needs to avoid adverse surgical complications caused by over-treatment, but also needs to avoid the harm of re-operation and early recurrence caused by insufficient surgical scope [18,19]. MRI not only has high soft tissue resolution, spatial resolution and tissue contrast, but also can be used for multi-dimensional, multi-directional and multi-parameter imaging. It is superior to ultrasound and CT in preoperative diagnosis of myographic invasion and lymph node metastasis of endometrial cancer, and does not produce ionizing radiation, so it is the best imaging method for endometrial cancer [19,20].

Endometrial cancer generally presents equal signal on T1WI, which is difficult to distinguish from normal uterine anatomy and is mainly

used to exclude uterine bleeding. T2WI generally presents a slightly higher or higher signal, and the lesion signal is lower than the high-signal layer of the endometrial and higher than the muscular layer signal [21,22]. Due to the advantages and disadvantages of various MRI imaging techniques, this study integrated multiple MRI imaging techniques to learn from each other to diagnose endometrial cancer before surgery [23]. This study included a total of 76 patients with endometrial cancer, including 50 patients with stage IA, 9 patients with stage IB, 10 patients with stage II, and 7 patients with stage III. The sensitivity and specificity of MRI in the diagnosis of stage IA, IB, II and III were 91.3% and 96.2%, respectively. 88.6%, 93.8%; 97.4%, 89.2%; 84.2%, 100%. The accuracy was 86.8% (66/76), and the Kappa value was 0.786, indicating high consistency. This is in line with a previous report on staging of 202 endometrial cancers diagnosed by 3.0 T MRI before surgery [23]. The specificity and sensitivity of this report were 76.7% and 94.3%, respectively. 98.4% and 100.0% in stage II, stage III was 98.3% and 75.0%. Among them, 1 case of stage IB was underestimated as stage IA, 3 cases of stage IA was overestimated as stage IB, 1 case of stage II was underestimated as stage IB, 2 cases of stage IA was overestimated as stage II, and 1 case of stage III was underestimated as stage II [23]. This may be related to the following reasons: (1) After menopause, the uterine wall becomes thin or the swelling growth of the lesion expands the uterine cavity, and the muscle layer becomes flattened under pressure and misestimates the depth of infiltration [24]. (2) The myometrium was bleeding at the time of examination, causing the boundary between the lesion and the myometrium to be blurred and difficult to judge [25,26]. (3) The degree of deep muscle infiltration was slight. (4) Combined with uterine fibroids and adenomyosis, compression deformation of the binding zone. In this study, there were 14 cases of uterine fibroids and 4 cases of adenomyosis[27,28]. (5) Preoperative MRI images showed no obvious abnormal enlargement of lymph nodes in the pelvic cavity, and the short diameter of the lymph nodes shown was less than 10 mm, but the pathological results showed that the nature of the lymph nodes had changed [29,30]. In addition, there are some shortcomings in this study, that is, there are fewer cases of endometrial cancer at stage IB, Stage II and Stage III in this study, and the conclusion is not convincing enough. It is expected that a large number of samples can be collected for further study, to make the study more accurate and representative.

The study's limitations include a relatively small sample size for certain stages of endometrial cancer, notably stage IB, stage II, and stage III, potentially impacting the generalizability of the findings. The results should be interpreted cautiously due to this limitation, as a larger sample size is essential to enhance statistical power and draw more robust conclusions about the diagnostic and staging accuracy of multi-parameter MRI in endometrial cancer. Comparing our findings with existing literature indicates consistency in highlighting the efficacy of MRI for preoperative staging, with our study's overall accuracy aligning with previous reports. However, discrepancies may arise from variations in sample characteristics, imaging protocols, and staging criteria across different studies. While our study provides valuable insights, future research with larger and more diverse cohorts is crucial to validate and expand upon these findings, addressing existing gaps in the literature and providing a more comprehensive understanding of multi-parameter MRI's diagnostic capabilities in endometrial cancer.

5. Conclusion

In conclusion, despite the study's limitations related to the sample size, our findings underscore the potential clinical utility of multi-parameter MRI in accurately diagnosing and staging endometrial cancer. The overall high accuracy and consistency with postoperative pathology results affirm the relevance of MRI in preoperative assessment, guiding clinicians in treatment planning. The study emphasizes the importance of further research with larger and more diverse cohorts to enhance the generalizability of results. Future investigations could explore refining imaging protocols, incorporating advanced techniques, and validating the utility of multi-parameter MRI in real-world clinical settings. Ultimately, this research contributes valuable insights that may inform advancements in the preoperative management of endometrial cancer, potentially improving patient outcomes and treatment strategies.

Ethical Approval

this study protocol was approved by the Ethics Committee of Yan'an Hospital Affiliated to Kunming Medical University.

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CRediT authorship contribution statement

Liqiong Liu: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lianbi Zhang:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Informed consent

Informed consent was obtained from all patients.

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