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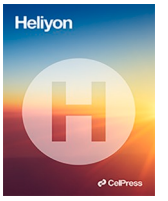

Research article

Ureteral endometriosis: MR imaging appearance for predicting complex procedures

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ABSTRACT

Rationale and objectives: To describe MRI characteristics of ureteral endometriosis (UE) in identifying intrinsic involvement of the ureteric wall and predicting complex procedures.
Methods: Thirty-three UE lesions in 30 patients treated for UE over a 20-year period were reviewed. A systematic analysis of 13 MRI (ureteric wall thickening, circumference, T1 signal, T2 signal, ureterectasis, lateral parametrial endometriosis (LPE), rectal endometriosis, the foregoing three-characteristic diameter, ovarian endometriomas, adenomyosis, paraurethral endometriosis) and 5 clinical (age, BMI, CA125, creatinine and rAFS stage) characteristics was performed. MRI results were compared to histology and surgical procedure performed (simple versus complex ureteral procedures).
Results: Twenty-five extrinsic and 8 intrinsic UE were pathologically identified. Twenty lesions underwent a simple procedure, and 12 underwent a complex procedure, with 1 ureteroscopic biopsy. There were significant differences in the characteristics of ureteric wall thickening, the diameter of dilated ureter and LPE, rectal endometriosis and adenomyosis between extrinsic and intrinsic UE ($p < 0.05$). UE was associated with LPE ($p = 0.033$). The criteria of ureteral wall thickening more accurately predicted intrinsic UE than circumference, but the AUC was not significant difference (AUC, 0.806 and 0.639; 95 % CI, [0.594, 0.937] and [0.419, 0.823], respectively; $p = 0.350$). There were significant differences in creatinine, thickening and adenomyosis between the simple and complex procedures ($p < 0.05$). In 11 lesions with the absence of ureterectasis, 4 lesions with hydronephrosis and thickening were intrinsic and underwent complex procedures, while 7 lesions extrinsic and simple.
Conclusions: Ureteric wall thickening as a analytical criterion may accurately predict intrinsic UE and complex ureteric procedures.

Abbreviations: UE, ureteral endometriosis; **LPE**, lateral parametrial endometriosis; **r-AFS**, the revised American Fertility Society; **AUC**, area under the ROC curve; **95 % CI**, 95 % confidence interval; **DIE**, deep infiltrating endometriosis; **TVS**, transvaginal sonography; **PACS**, picture archive and communication system; **CA**, carbohydrate antigen; **T1WI**, T1-weighted imaging; **T2WI**, T2-weighted imaging; **CE-T1WI**, contrast-enhanced T1-weighted imaging; **3D**, three-dimensional; **Acc**, accuracy; **Sen**, sensitivity; **Spe**, specificity; **PPV**, positive predictive value; **NPV**, negative predictive value.

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1. Introduction

Endometriosis, defined as the presence of endometrial glands and/or stroma cells outside the endometrial cavity, frequently occurs in women of reproductive age (approximately 10 %) [1]. The most serious type of endometriosis, known as deep infiltrating endometriosis (DIE), is characterized by endometriotic infiltration under the peritoneum at a depth of at least 5 mm or involvement of viscera, including the uterus, vagina, rectum, bladder, or ureter [2–5]. Ureteral endometriosis (UE) is a rare type of DIE, and the prevalence ranges from 9 to 23 % in cases of urinary tract endometriosis [6]. The average age range for UE involvement is between 30 and 35 years and most commonly is unilateral, affecting the lower ureter 3–4 cm above the vesico-ureteral junction. Unilateral ureteral endometriosis has been described in 58%–90 % of cases [7].

The symptoms of UE are nonspecific, such as dysmenorrhea, dyspareunia and nonmenstrual pelvic pain, and are clinically silent in up to 30 % of UE patients [6]. Therefore, it is difficult to diagnose UE early [8,9]. Sometimes progressive upper urinary tract obstruction leads to the silent loss of kidney function. UE is classically divided into extrinsic and intrinsic pathological types according to the depth of ureteric wall infiltration by endometriosis. Extrinsic UE (80 %) is the most common type involving the adventitia, and intrinsic UE (20 %) affected tissue from the muscularis to the mucosal layers [10–12]. Seracchioli *et al.* [11] describe two histological patterns: a fibrotic pattern characterized by fibrotic tissue only and an endometriotic pattern.

The diagnostic gold standard is laparoscopy and pathological confirmation, with the range from the onset of endometriosis to surgical diagnosis usually being 6–11 years [13]. Early preoperative diagnosis and accurate mapping of the distribution of pelvic endometriosis are prerequisites for radical surgery in UE.

Transvaginal sonography (TVS) is the first-line technique for the assessment of UE [14], and as a reliable tool, it not only diagnoses UE but also maps the level and degree of obstruction [15]. However, TVS diagnosis heavily relies on the operator's experience. Ureteral endoscopy is an invasive imaging method that can directly visualize edematous and irregular blue nodules in contact with the ureter wall and allow intraluminal ultrasonography and a biopsy. However, ureteral endoscopy is not used in clinical practice due to its invasiveness and inability detect extrinsic UE [12]. Magnetic resonance imaging (MRI) can provide an evaluation of UE type and a large field of view, including detection of subperitoneal endometriotic involvement, which remains the reference technique for DIE and is particularly recommended prior to surgery [12,16,17]. Lateral parametrium was the region located between the uterus and pelvic sidewall. Lateral parametrial endometriosis (LPE) can be associated with UE and hypogastric plexus, causing severe functional impairment and painful symptoms. Mariani et al. descried the LPE comprehensively in a TVS study [18], while MRI has not yet been reported. And there have been no reports of UE lesions with the absence of ureterectasis in neither TVS nor MRI.

The purpose of this study was to describe the MRI characteristics of UE in identifying intrinsic involvement of the ureteric wall and predicting complex procedures.

2. Materials and methods

This single-center analysis was approved by the Ethics Committee of Shenzhen People's Hospital (Ethics Number: [2019] 006) in accordance of the Declaration of Helsinki, and written informed consent was waived due to the retrospective nature of the study.

2.1. Study population

This was a retrospective consecutive study between on 123 cases of clinically suspected ureteral endometriosis through the surgical database in Shenzhen People's Hospital. Clinically suspected diagnosis was established on the basis of symptoms, physical examination and imaging examination (TVS and MRI) after excluding urologic causes of intrinsic or extrinsic ureteral stenosis, such as stones, primary or metastatic cancer, retroperitoneal lymphadenopathy, idiopathic retroperitoneal fibrosis and infections [19].

Seventy-six patients underwent both TVS and abdominal-pelvic MRI within two weeks preoperatively by retrieving the picture archive and communication system (PACS), and 30 patients with surgically and pathologically confirmed UE were ultimately enrolled (Supplementary Material Fig. S1). For each patient, 5 clinical data points, including age, BMI, carbohydrate antigen (CA) 125, creatinine and rAFS stage, were collected from medical records, and imaging data were collected from PACS. Patient follow-up was performed until March 2023.

2.2. Surgery and pathological examination

Twenty-nine patients underwent laparoscopic surgery and intraoperative rAFS stage, whereas one patient received nonsurgical treatment with ureteroscopic biopsy and ureteral stent implantation. All UE lesions were confirmed pathologically.

The surgical treatment of UE aims to relieve ureteral obstruction and avoid recurrence [12]. The surgical procedures included ureterolysis, ureteral resection with end-to-end anastomosis, ureteroneocystostomy and nephroureterectomy [12,20]. In the present study, the surgical procedure of conservative ureterolysis was defined as a simple procedure, and radical procedures, *i.e.,* ureterolysis requiring dissection, ureterolysis requiring shaving of ureteral adventitia, ureteral resection and nephroureterectomy, were defined as complex procedures [12].

Two pathologists (H. Jin [with 10 years of diagnostic experience] and Y. Wang [with 10 years of diagnostic experience]) reviewed pathological sections in consensus. UE lesions were divided into extrinsic and intrinsic pathological types according to the depth of ureteric wall infiltration by endometriosis. Extrinsic UE was defined as when endometrial glands and/or stroma cells were found

Table 1
Comparison the diagnostic efficacy of TVS and MRI.

	All UE lesions		*P* value	UE lesions absent of ureterectasis		*P* value
	MRI (+) n (%)	MRI (−) n (%)		MRI (+) n (%)	MRI (−) n (%)	
TVS (+)	11 (44)	1 (11.1)	0.002	1 (50)	1 (14.3)	0.618
TVS (−)	13 (52)	8 (88.9)		3 (50)	6 (85.7)	

within the adventitia or periureteral tissue and intrinsic UE was within the muscularis and/or urinary mucosa [11,12].

2.3. MRI protocol

All scans were performed before surgery on a 3.0T MRI scanner (Siemens Magnetom Skyra, Erlangen, Germany) with a phased-array 8-channel sensitivity encoding abdominal coil. Before examination, patients were instructed to fast for 6 h, and the recommended water intake was moderate to ensure that the bladder was not full to the extent that it would cause motion artifacts. Vaginal/rectal opacification with sterile gel and antiperistaltic agents was not applied. The sequence parameters were as follows: T1-weighted imaging (T1WI) and conventional and fat-suppressed T2-weighted imaging (T2WI). Gadopentetate meglumine (Guangzhou Consun Pharmaceutical, Guangzhou, China) was intravenously administered at a dose of 0.1 mL/kg body weight. Contrast-enhanced T1-weighted imaging (CE-T1WI) of the uterine corpus was obtained at a delay period of 80–120 s after beginning contrast material injection, and conventional T1WI and three-dimensional (3D) fat-saturated were performed after injection.

2.4. Image analysis

Two radiologists (R. Ling [with 23 years of diagnostic experience] and Q. Yi [with 13 years of diagnostic experience]) reviewed the MR images to evaluate the characteristics in consensus. Both were aware that study participants had UE, but they were blinded to the rest of the histological types and surgical results. TVS results based on retrieving reports and images from PACS.

13 MRI characteristics included ureteric wall thickening, the contact circumference between the ureter and the endometriosis lesion (classified into equal to 360°, 180°–360° and <180°), T1 signal and T2 signal of UE, ureterectasis, LPE, rectal endometriosis, the foregoing three-characteristic diameter, the presence of a nodule or adhesions of ovarian endometriomas, adenomyosis and paraurethral endometriosis (classified into LPE, ovarian endometriomas and multiple lesions). A ureteral dilatation diameter greater than or equal to 6 mm was defined as ureterectasis [14]. The measurement of diameter ureterectasis, LPE and rectal endometriosis was carried out on transverse view.

MRI predictive types of extrinsic and intrinsic UE used the following analytical criteria [16]: (1). The contact circumference between the ureter and the endometriosis lesion was classified as extrinsic UE if the circumference was <180° and intrinsic UE if the circumference was equal to 360°, and the predictive type was based on other MRI characteristics if the circumference was 180°–360°. (2). Peri-ureteric fat signal disappearance on T2WI. (3). Extrinsic compression resulted from a lesion in contact with the ureter or surrounded by a contiguous lesion.(4). The size and retractile appearance of the parametrial nodule.

2.5. Statistical analysis

Descriptive statistics were used to present continuous variables as the mean (range) and categorical variables as numbers (%). Continuous variables were compared with the unpaired *t*-test if the data were distributed normally or the ManneWhitney *U* test if the data were distributed nonnormally. The choice of the nonparametric statistics was based on the limited size of the present study. Fisher's exact test for categorical variables was used for comparisons between MRI and clinical characteristics in pathological types and surgical procedures types. A p-value of < 0.05 was considered significant statistically. Sensitivity and specificity were assessed for the analytical criteria of ureteric wall thickening and the circumference by using receiver operating characteristic (ROC) curves. Analyses were performed using IBM SPSS Statistics 26.0 software (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp) and MedCalc (Version 22.007, https://www.medcalc.org/).

3. Results

Thirty patients between 22 and 53 years old (median age: 39 years old) were included in the present study. Twenty-seven patients presented with unilateral ureteral involvement: 20 on the left, 7 on the right and 3 with bilateral involvement. Thus, there were 33 UE lesions in total. The characteristics of the population are summarized in Electronic Supplementary Material Table S1.

3.1. The diagnostic efficacy of TVS and MRI

Twenty-two lesions in 33 UE lesions were correctly diagnosed by MRI according the analytical criteria of the circumference, with a 66.7 % (22/33) accuracy rate, and 12 lesions by TVS, with a 36.4 % (12/33) accuracy rate. This difference was statistically significant ($p = 0.002$).

Table 2
MRI characteristics of UE lesions according to the pathological types.

Characteristic	Pathological types		All n = 33 (%)	Statistics Value	*P* value
	Extrinsic UE n = 25 (%)	Intrinsic UE n = 8 (%)			
MRI types					
Extrinsic UE	11 (44)	2 (25)	13 (39.4)		–
Intrinsic UE	7 (28)	6 (75)	13 (3.3)		
Ill defined	7 (28)	0 (0)	7 (27.3)		
MRI signs rowhead					
T1 signal					0.304
Hypointensity	17 (68)	4 (50)	21 (63.6)		
Mixed intensity	8 (32)	4 (50)	12 (36.4)		
T2 signal					0.381
Hypointensity	16 (64)	4 (50)	20 (60.6)		
Mixed intensity	9 (36)	4 (50)	13 (39.4)		
Circumference					>0.05[b]
<180°	8 (32)	1 (12.5)	9 (28.3)		
180°–360°	6 (24)	2 (25)	8 (24.2)		
360°	4 (16)	5 (62.5)	9 (27.3)		
Ill defined	7 (28)	0 (0)	7 (21.2)		
Ureteric wall					0.013[c]
Thickening	4 (16)	7 (87.5)	11 (33.3)		
Absent of thickening	14 (56)	1 (12.5)	15 (45.5)		
Ill defined	7 (28)	0 (0)	7 (21.2)		
Ureterectasis					0.379
Ureterectasis	17 (68)	5 (62.5)	22 (66.67)		
Absent of ureterectasis	8 (32)	3 (37.5)	11 (33.3)		
Diameter of dilated ureter[a]	7 [6–14]	7.5 [7–11]	7 [6–14]	−4.357	0.001
LPE	25 (100)	8 (100)	33 (100)	–	–
Diameter of axis of LPE[a]	20.5 [11–41]	23 [12–31]	22 [11–41]	−5.129	0.001
Rectum					0.008
RE	20 (80)	2 (25)	22 (66.67)		
Non-RE	5 (20)	6 (75)	11 (33.3)		
Diameter of axis of RE[a]	16 [10–46]	16, 30	16 [10–46]	–	
Ipsilatera ovary					0.091
Emt	18 (72)	3 (37.5)	21 (63.6)		
Non-Emt	7 (28)	5 (62.5)	12 (36.4)		
Uterus					0.026
Adenomyosis	18 (72)	2 (25)	20 (60.6)		
Nonadenomysis	7 (28)	6 (75)	13 (39.4)		
Paraureteral EM				–	–
LPE	15 (60)	8 (100)	23 (69.7)		
Ovarian Emt	3 (12)	0 (0)	3 (9.1)		
Multiple lesions	7 (28)	0 (0)	7 (21.2)		

UE, ureteral endometriosis; LPE, lateral parametrial endometriosis; RE, rectal endometriosis; DIE, Deep infiltrating endometriosis; Emt, endometriomas.

[a] Median, with ranges in parentheses.

[b] Excluding 7 ill defined lesions, the difference between the group of <180° and the group of 180°–360° is not statistically significant ($p = 0.453$), none of between the group of 180°–360°and the group of 360° ($p = 0.218$) and between the group of <180° and the group of 360° ($p = 0.066$).

[c] Excluding 7 ill defined lesions.

In the present study, there were 11 UE lesions with the absence of ureterectasis, making it difficult to diagnose. Fortunately, 4 UE lesions were correctly diagnosed by MRI with a 36.4 % (4/11) accuracy rate, and 1 lesions by TVS with a 9 % (1/11) accuracy rate. The difference was not statistically significant ($p = 0.618$). A comparison of MRI and TVS was shown in Table 1.

3.2. MRI characteristics

According to the pathological sections, the UE lesions were divided into two groups: the intrinsic UE group and the extrinsic UE group. There were 8 (8/33, 24.2 %) intrinsic UE lesions and 25 (25/33, 75.6 %) extrinsic UE lesions pathologically. The MRI characteristics of UE lesions according to the pathological types were shown in Table 2.

On T1WI, intrinsic UE lesions showed hypointensity (n = 4) and mixed intensity (n = 4), while extrinsic UE lesions showed hypointensity (n = 17) and mixed intensity (n = 8), and the difference was not statistically significant ($p = 0.304$). On T2WI, intrinsic UE lesions showed hypointensity (n = 4) and mixed intensity (n = 4), while extrinsic UE lesions showed hypointensity (n = 16) and mixed intensity (n = 9), and the difference was not statistically significant ($p = 0.381$).

According to the analytical criteria of the circumference, MRI predicted 6 intrinsic and 11 extrinsic UE lesions, correctly. Seven ill defined UE lesions were excluded from statistics for difficulty to further categorize the types. It seemed that the circumference less than 180° and the circumference between 180° and 360° tended to extrinsic pathological type, and the circumference equal to 360° tended

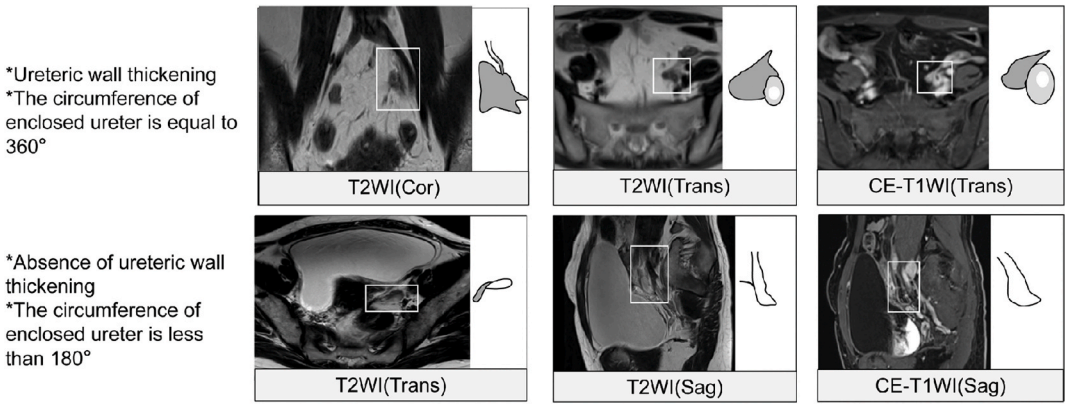

Fig. 1. The criteria diagrams of both ureteric wall thickening and the contact circumference between the ureter and the endometriosis lesion. According to multiple parameters characteristics of UE on T2WI and enhanced T1WI, the characteristic of ureteric wall (classified into thickening and absence of thickening) and the circumference of enclosed ureter (classified into equal to 360°, 180°-360°and <180°).

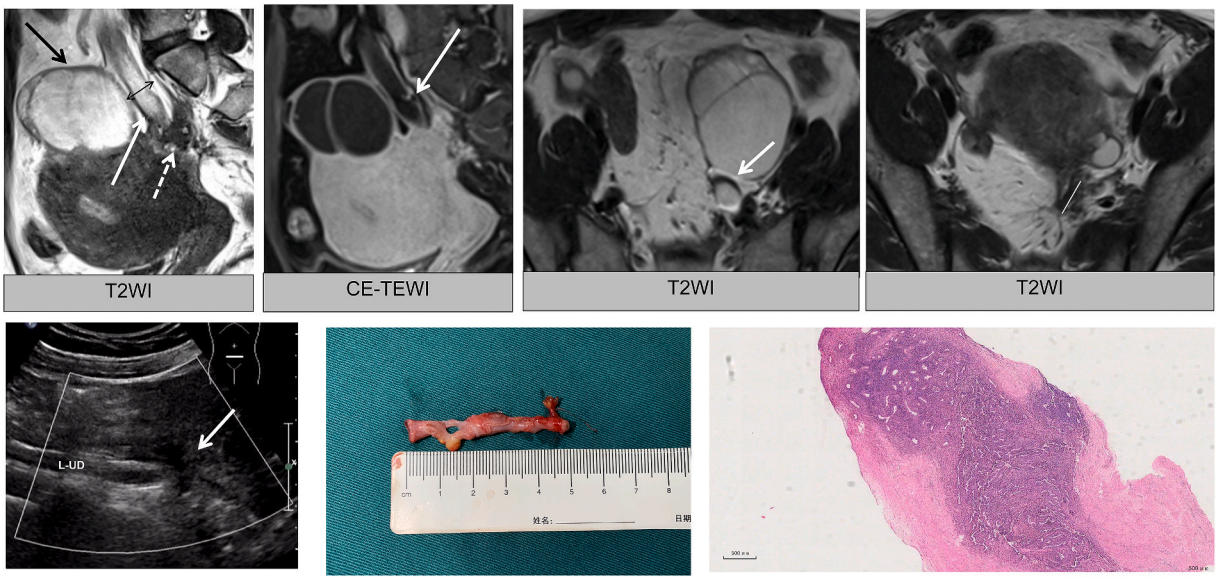

Fig. 2. Evaluation of ureteric wall thickening with ureterectasis in a 50-year-old women with history of lumbar pain during menstrual period. Complex ureteric procedure (*i.e.* ureteroneocystostomy) performed, and intrinsic UE confirmed pathologically. Sagittal T2-weighted MR image shows a endometriosis nodular involved the left lower ureter and posterior uterus (white dashed arrow). The spike nodular shows hypointensity mixed spot high signal and defines as mixed intensity. The circumference of which enclosed lower ureter is equal to 360°. Left ureter shows dilated (white arrow) with the diameter of 11 mm (double-headed black arrow) defined as ureterectasis. Posterior uterus muscle layer thickening indicates adenomyosis. In addition, left ovarian endometriomas shows hyperintensity on T2WI and adhered to the uterine fundus (black arrow). Transverse T2-weighted MR images show the transverse diameter of parametrium endometriosis nodule is 2.4 cm (dashed line). Transabdominal sonography shows ureterectasis caused by a spike endometriosis nodular (white arrow). The morphology of the resected ureter performs irregular. The presence of endometrial glands and stroma cells is observed in the adventitia, the muscularis and the mucosal layers of the ureteric wall, which confirms intrinsic UE (haematoxylin and eosin [H&E] stain, × 2).

to nearly equal prediction between intrinsic and extrinsic pathological types. However, the difference between the group of <180° and the group of 180°–360° was not statistically significant ($p = 0.453$), none of between the group of 180°–360°and the group of 360°($p = 0.218$) and none of between the group of <180° and the group of 360°($p = 0.066$).

The characteristic of ureteric wall thickening was first raised as a analytical criterion (Fig. 1). In 8 intrinsic pathological types, 7 (7/8, 87.5 %) lesions performed the characteristic and 1 (1/8, 12.5 %) lesion absent of that. In 25 extrinsic pathological lesions, 4 (4/25, 16 %) lesions performed the characteristic, 14 (14/25, 56 %) lesions absent of that, and 7 (7/25, 28 %) lesions ill defined, which were excluded from statistics for difficulty to further categorize the types. The characteristic of ureteric wall thickening seemed to be more frequently associated with intrinsic UE lesions than extrinsic UE lesions, and the difference was statistically significant ($p = 0.013$)

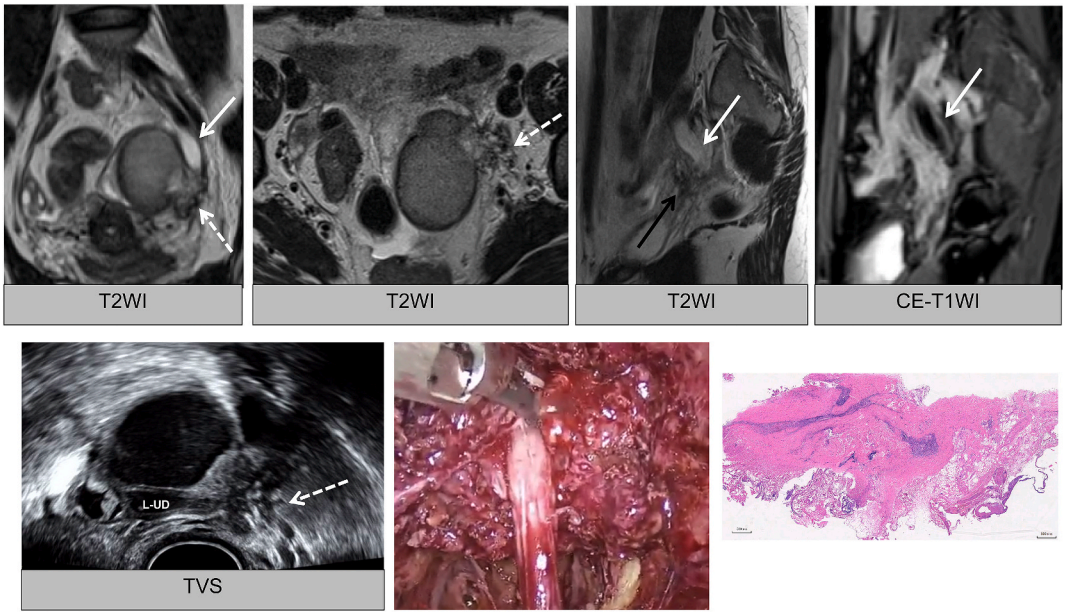

Fig. 3. Evaluation the absence of ureteric wall thickening with ureterectasis in a 37-year-old women with history of pelvic mass. Simple ureteral procedure (*i.e.*ureterolysis) performed, and extrinsic UE confirmed pathologically. Coronal T2-weighted MR image shows a endometriosis nodular involved the left lower ureter (white dashed arrow) and the circumference of which enclosed lower ureter is equal to 360°. Left ureter shows dilated (white arrow) with the diameter of 8 mm. Transverse T2-weighted MR image shows a spike parametrium endometriosis nodule (white dashed arrow) and a oval ovarian endometriomas, which is at the right lateral of parametrium nodule. Sagittal T2-weighted and contrast-enhanced T1-weighted MR images show absent of the ureteric wall thickening characteristic. TVS shows left ureterectasis caused by a spike endometriosis nodular (white dashed arrow). Laparoscopy shows the endometriosis lesion enclosed the lower ureter, and after ureterolysis the ureter recovers the normal morphology. The presence of endometrial glands and stroma cells is observed in the adventitia layers of the ureteric wall, which confirms extrinsic UE (haematoxylin and eosin [H&E] stain, × 2).

Table 3
Two MRI analytical criteria of the circumference and the ureteric wall thickening for predicting pathological types.

Characteristics	AUC	95 % CI	Sen (%)	Spe (%)	PPV(%)	NPV(%)	Acc(%)	*P* value
Circumference	0.639	0.419, 0.823	66.67	61.11	36.4	84.6	62.5	0.35
Thickening	0.806	0.594, 0.937	83.33	77.78	55.6	93.5	79.2	

UE, ureteral endometriosis; AUC, area under curve; Sen, sensitivity; Spe, specificity; PPV, positive predictive value; NPV, negative predictive value; Acc, Accuracy; CI, confidence interval.

(Figs. 2 and 3).

The AUC (area under the ROC curve) of the analytical criterion of ureteric wall thickening to predict pathological types was 0.806 (95 % CI [0.594–0.937]), and the circumference was 0.639 (95 % CI [0.419–0.823]). The performance of the ureteric wall thickening criterion was better than that of the circumference in term of Acc (79.2 % and 62.5 %), Sen (83.3 % and 66.7 %), Spe (77.8 % and 61.1 %), PPV (55.6 % and 36.4 %) and NPV (93.5 % and 84.6 %), respectively. But the difference was not statistically significant ($p = 0.35$; Table 3 and Electronic Supplementary Material Fig. S2).

The diameter of the dilated ureter of intrinsic UE lesions was 7.5 (7–11) mm, which was slightly greater than that of extrinsic UE lesions, with a mean (range) diameter of 7 (6–14) mm, and the difference was statistically significant ($p = 0.001$). Lesions with rectal endometriosis and adenomyosis were more frequent in extrinsic than in intrinsic UE, and the difference was statistically significant ($p = 0.008$ and $p = 0.026$, respectively).

Endometriosis lesions associated with UE including LPE, ovarian endometriomas and multiple lesions. LPE predominates, which peri-ureteric endometriosis lesion was LPE in 25 (25/25, 100 %) extrinsic pathological lesions and 8 (8/8, 100 %) intrinsic pathological lesions. The diameter of LPE in intrinsic pathological type with a mean (range) transverse axis of 23 (12–31) mm was greater than that of extrinsic pathological type with a mean of 20.5 (11–41) mm, and the difference was statistically significant ($p = 0.001$).

3.3. Clinical and surgical characteristics

In 33 UE lesions, 20 underwent a simple procedure, 12 lesions underwent a complex procedure, and one lesion not received surgical

Table 4
MRI characteristics and clinical characteristics according to the surgical procedures.

Characteristic	Simple procedure n = 20 (%)	Complex procedure n = 12 (%)	ALL n = 32[b] (%)	Statistics Value	*P* value
Age (years)[a]	38 [24–53]	43.5 [22–50]	39 [22–53]	−1.893	0.058
BMI(kg/m^2)[a]	21.45 [18.9–26.21]	23.39 [16.8–28.55]	22.43 [16.8–28.55]	−1.421	0.155
CA 125 (U/ml)[a]	95.98 [16.06–640.6]	60.53 [16–640.6]	81.88 [16–640.6]	−1.09	0.276
Creatinine (μmoI/L)[a]	57.8 [39.7–84]	73.5 [57–104]	66 [39.7–104]	−3.219	0.001
rAFS stage				–	0.379
1∼3	3 (15)	4 (33.3)	7 (21.9)		
4	17 (85)	8 (66.7)	25 (78.1)		
Pathological types				–	–
Extrinsic UE	19 (95)	5 (41.7)	24 (75)		
Intrinsic UE	1 (5)	7 (58.3)	8 (25)		
MRI characteristics					
Ureteric wall					0.004[c]
Thickening	2 (10)	9 (75)	11 (34.4)		
Absent of thickening	11 (55)	3 (25)	14 (43.8)		
Ill defined	7 (35)	0 (0)	7 (21.9)		
Circumference					>0.05[d]
<180°	5 (25)	4 (33.3)	9 (28.1)		
180°–360°	5 (25)	2 (16.7)	7 (21.9)		
360°	3 (15)	6 (50)	9 (28.1)		
Ill defined	7 (35)	0 (0)	7 (21.9)		
Ureterectasis					0.465
Ureterectasis	12 (60)	9 (75)	21 (65.6)		
Absent of ureterectasis	8 (40)	3 (25)	11 (34.4)		
Diameter of dilated ureter[a]	6.5 [6–14]	7.5 [6–11]	7 [6–14]		0.338
Rectum					0.383
RE	14 (70)	7 (58.3)	21 (65.6)		
Non-RE	6 (30)	5 (41.7)	11 (34.4)		
LPE	20 (100)	12 (100)	32 (100)	–	–
Ipsilateral ovary					0.503
Emt	12 (60)	8 (66.7)	20 (62.5)		
Non-Emt	8 (40)	4 (33.3)	12 (37.5)		
Uterus					0.03
Adenomyosis	15 (75)	4 (33.3)	19 (59.4)		
Nonadenomyosis	5 (25)	8 (66.7)	13 (40.6)		
Paraureteral EM				–	–
LPE	12 (60)	10 (83.3)	22 (68.8)		
Ovarian Emt	3 (15)	0 (0)	3 (9.4)		
Multiple lesions	5 (25)	2 (16.7)	7 (21.9)		

BMI, body mass index; AFS, American Fertility Society; UE, ureteral endometriosis; RE, rectal endometriosis; LPE, lateral parametrial endometriosis; DIE, Deep infiltrating endometriosis; Emt, endometriomas.

[a] Median [interquartile range].

[b] Excluding 1 lesion which not received surgical treatment with ureteroscopic biopsy and ureteral stent implantation.

[c] Excluding 7 ill defined lesions.

[d] Excluding 7 ill defined lesions, there are not statistically significant between the group of <180° and the group of 180°–360° is ($p = 0.451$), none of between the group of 180°–360° and the group of 360°($p = 0.319$) and none of between the group of <180° and the group of 360° ($p = 0.157$).

treatment with ureteroscopic biopsy and ureteral stent implantation. Seven lesions of intrinsic pathological type and 5 lesions of extrinsic pathological type underwent complex procedures, and one intrinsic and 19 extrinsic lesions underwent simple procedures. MRI characteristics and clinical characteristics, according to the type of surgical procedure, were shown in Table 4.

Age, BMI, CA 125, creatinine, and rAFS (the revised American Fertility Society) stage comprised the clinical characteristics. The mean (range) creatinine level in the present study was 66 (39.7–104) μmoI/L (reference range: 44–133 μmoI/L), and none of the patients experienced clinical renal dysfunction. The mean (range) creatinine level in the simple procedure group was 57.8 μmoI/L (39.7–84 μmoI/L), and that in the complex procedure group was 73.5 μmoI/L (57–104 μmoI/L), and the difference was statistically significant ($p = 0.001$). The rest clinical characteristics were not statistically significant ($p > 0.05$).

There were 9 (9/12, 75 %) UE lesions accompanied by the characteristic of ureteric wall thickening performed complex procedure and 11 (11/20, 55 %) lesions not accompanied by the characteristic performed simple procedure. The lesion accompanied by the characteristic of ureteric wall thickening performed more tend to a complex procedure than a simple procedure, and the difference was statistically significant ($p = 0.04$). Lesions accompanied by adenomyosis more frequent performed simple procedure than complex procedure, and the difference was statistically significant ($p = 0.03$). The rest MRI characteristics were not statistically significant between the simple procedure group and the complex procedure group ($p > 0.05$).

3.4. UE lesions with the absence of ureterectasis

There were 11 UE lesions with the absence of ureterectasis, of which, 7 lesions underwent a simple procedure and 4 underwent a

Table 5
Clinical characteristics and MRI characteristics of UE with the absence of ureterectasis.

Case NO.	1	2	3	4	5	6	7	8	9	10	11
Age (years)	38	38	44	43	49	36	36	42	37	39	32
BMI (kg/m^2)	19.26	19.26	23.81	20.45	20.44	19.73	23.37	26.21	26.10	23.43	22.43
CA 125 (U/ml)	104.8	104.8	291.6	49.05	137	201.1	213.7	207.7	55.23	95.98	640.6
Creatinine (μmoI/L)	42	42	71	48.9	70	76	57	66	87	46.3	66
rAFS	96	96	140	130	10	72	23	110	70	48	118
Symptoms	Dys	Dys	Dys and FM	Dys	Dys	Dys and FM	Dys	Dys	Dys	Dys	Dys
Previous surgery for EM	–	–	–	–	–	–	–	–	+	–	–
MRI characteristics											
Morphology of ipsilateral kidney	normal	normal	HN	normal	HN	normal	HN	normal	HN	normal	normal
Circumference	Ill defined	Ill defined	<180°	Ill defined	<180°	Ill defined	360°	180°–360°	Ill defined	Ill defined	Ill defined
Ureteric wall thickening	–	–	+	–	+	–	+	–	+	–	–
Diameter of axis of RE (mm)	10	10	10	23	NA	22	0	26	30	0	12
Diameter of axis of LPE (mm)	19	16	22	41	21	23	20	27	25	16	22
Ipsilateral ovarian Emt	+	+	+	+	+	+	–	+	+	+	–
Contralateral ovarian Emt	+	+	+	+	+	+	+	+	–	+	+
Adenomyosis	+	+	+	+	+	+	–	+	–	+	+
Paraureteral EM	Emt	Emt	LPE	LPE	LPE	LPE	LPE	LPE	LPE	LPE	LPE
Pathological types	extrinsic	extrinsic	intrinsic	extrinsic	intrinsic	extrinsic	intrinsic	extrinsic	intrinsic	extrinsic	extrinsic
Surgery procedure	simple	simple	complex	simple	complex	simple	complex	simple	complex	simple	simple

UE, ureteral endometriosis; BMI, body mass index; AFS, American Fertility Society; EM, endometriosis; RE, rectal endometriosis; Emt, endometriomas; Dys, dysmenorrhea; FM, frequent micturition; HN, hydronephrosis; LPE, lateral parametrial endometriosis.

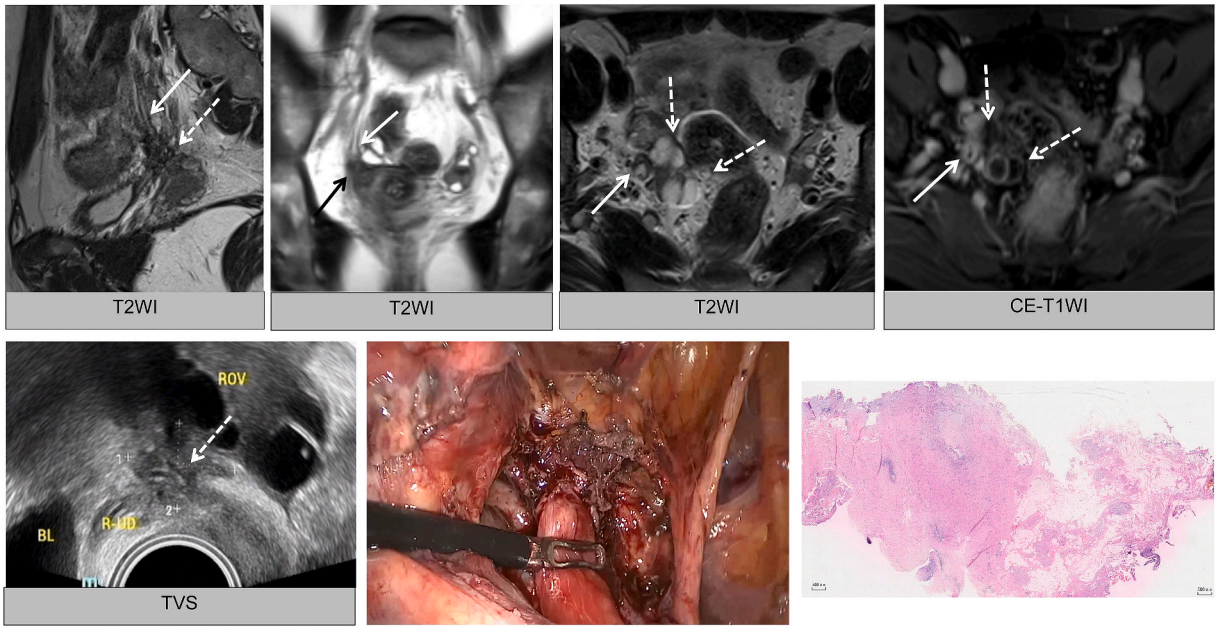

Fig. 4. Evaluation of ureteric wall thickening with the absence of ureterectasis in a 37-year-old women with history of lower abdominal pain during menstruation. Complex ureteral procedures (*i.e.* ureteral resection) performed, and intrinsic UE confirmed pathologically. Sagittal and coronal T2-weighted MR image shows a endometriosis nodular involved the right lower ureter (white dashed arrow) and the circumference of which enclosed lower ureter is 180°–360°. Right ureter shows the absence of ureterectasis (white arrow). Transverse T2-weighted and contrast-enhanced T1-weighted MR images show right ureteric wall thickening (white arrow) and right ovarian endometriomas (white dash arrow). TVS shows right parametrium endometriosis nodule (white dashed arrow) adhesions to right lower ureter with the absence of ureterectasis. Laparoscopy shows the endometriosis lesion enclosed the lower ureter, and ureteral resection is performed. The presence of endometrial glands and stroma cells is observed in the muscularis layers of the ureteric wall, which confirms intrinsic UE (haematoxylin and eosin [H&E] stain, × 2).

complex procedure. Seven lesions with the r-AFS classification greater than 40 were classified as stage IV. In all lesions, creatinine was less than the reference of 133 μmoI/L. The clinical and MRI characteristics were shown in Table 5.

Eleven lesions were silent and difficult to define directly, and fortunately there were 4 lesions showed mild ipsilateral hydronephrosis. And the 4 lesions showed the ureteric wall thickening characteristic above the portion close to the vesico-ureteral junction, and intrinsic UE was correctly predicted on MRI, conformed pathologically after complex procedure. At the same time, the remaining 7 lesions had missed diagnoses. Fortunately, the lesions were extrinsic UE and underwent a simple procedure (Figs. 4 and 5).

4. Discussion

The present study demonstrated that a dedicated MRI analysis of UE, taking into account ureter and paraurethral characteristics, may indicate, with high accuracy, the prediction of intrinsic UE and the need for radical procedures. The characteristics of ureteric wall thickening, dilated ureter diameter ≧7.5 mm, transverse axis of LPE≧23 mm, rectal endometriosis and adenomyosis were more likely to be intrinsic UE lesions. This paper described the characteristic of thickening ureteric wall as a analytical criterion for the first time to predict intrinsic UE lesions, and the AUC was 0.806 (95 % CI [0.594–0.937]). The lesion accompanied by the characteristic of ureteric wall thickening performed more tend to complex procedure than simple procedure, and the difference was statistically significant ($p = 0.04$). In UE lesions with the absence of ureterectasis, the characteristics of both hydronephrosis and ureteric wall thickening were the most predictive characteristics of intrinsic and complex procedures. Paraurethral endometriosis classified into LPE, ovarian endometriomas and multiple lesions, and the LPE predominates in the cause of UE. Therefore, although difficult, a precise MRI preoperative estimation may help the surgeon in the decision-making process to reduce postoperative complications [21].

TVS is the first-line technique for the assessment of UE and it should be performed with suspicious of UE after ultrasound. In a meta-analysis, the sensitivity and specificity of diagnosing UE on TVS were 87 % and 100 % and those of diagnosing on MRI were 97 % and 100 %, respectively [13,22]. However, in the present study, both TVS and MRI underperformed compared to other studies because there were 11 UE lesions with the absence of ureterectasis, it was difficult to define and classify the types.

Intrinsic UE causes ureteral muscularis proliferation and fibrosis, resulting in a thickening ureteric wall, rarely with polypoid urothelial extension. Extrinsic UE involves the ureteral adventitia and adjacent connective tissue, which can result in ureter encasement and compression [23]. The characteristic cannot be observed on TVS. The present study estimated the characteristic through multiple parameters on T2WI and enhanced T1WI. The AUC of the criterion of ureteric wall thickening was 0.806 (95 % CI [0.594–0.937]), and the Acc (accuracy), Sen (sensitivity), Sep (specificity), PPV (positive predictive value) and NPV (negative predictive value) were 79.2 %, 83.33 %, 77.78 %, 55.6 % and 93.5 %, respectively. The AUC of the circumference characteristic, a

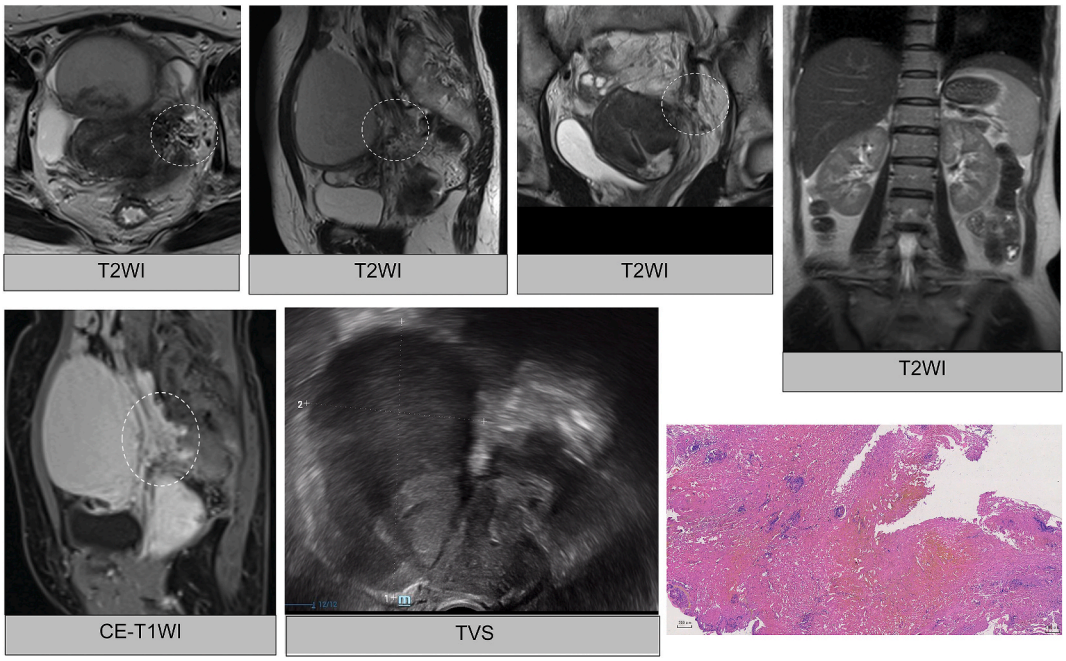

Fig. 5. Evaluation absent of ureteric wall thickening and ureterectasis in a 43-year-old women with history of secondary dysmenorrhea with progressive aggravation. Simple ureteral procedure (*i.e.*ureterolysis) performed, and extrinsic UE confirmed pathologically. Transverse, sagittal and coronal T2-weighted MR images show left parametrium endometriosis lesion (dashed circle). The left lower ureter was not observed because it is absent from ureteral dilation and hydronephrosis. Sagittal contrast-enhanced T1-weighted MR image shows absent of ureteric wall thickening. TVS shows an ovarian endometriomas and the normal morphology of both right ureter and kidney. Ureterolysis is performed and the presence of endometrial stroma cells in the adventitia layers of the ureteric wall confirms extrinsic UE (haematoxylin and eosin [H&E] stain, × 2).

classically analytical criteria, was 0.639 (95 % CI [0.419–0.823]), and the Acc, Sen, Spe, PPV and NPV were 62.5 %, 66.67 %, 61.11 %, 36.4 % and 84.6 %, respectively. Thus, it can be seen that the criterion of a ureteric wall thickening predicted intrinsic UE lesions better than that of circumference. To the best of our knowledge, this is the first relevant report. A large sample is still needed for testing.

It is important to note that 11 UE lesions were difficult to diagnose due to the absence of ureterectasis and normal renal function. There is often upstream ureteral mild dilatation with a normal diameter of the downstream ureter, which made it ill defined the existence of UE lesions [23,24]. There are rare reports of the absence of ureteral dilation and no imaging reports. Arena et al. reported that the transverse diameter of posterior DIE nodule ≧1.8 cm had a greater likelihood of ureteral involvement [25]. A multivariable fractional polynomial model showed that UE was significantly associated with adenomyosis, lateral parametrial endometriosis, and previous surgery for endometriosis [25]. Fortunately, in the present study, 4 UE lesions with the characteristic of lower ureteric wall thickening were fortunately observed on T2WI (Fig. 3), accompanied by mild hydronephrosis. And the lesions performed complex produces (*i.e.*ureteral resection and ureteral reimplantation), confirmed intrinsic UE pathologically, and showed no recurrence at follow-up after 5 and 45 months. Although the remaining 7 UE lesions missed to diagnose, extrinsic UE was confirmed pathologically during laparoscopy, and a simple procedure was performed (Fig. 4). It is highly recommended that patients undergoing surgery for DIE should have routine intraoperative retroperitoneal identification and warrant ureteral assessments [26,27].

This is the first time that LPE has been described on MRI. The lateral parametrium, the area between the uterus and pelvic sidewall, is primarily made up of retroperitoneal connective areolar tissue that envelops the visceral branches of the hypogastric vessels. LPE is closely associated with severe functional impairment and severe dysmenorrhea [28,29]. Patients with LPE always have a concurrent diagnosis of USL endometriosis, and the presence of USL involvement can raise the risk of LPE [30,31] and the likelihood of ureteral involvement [18,32–34]. Some studies have stressed the significance of taking the potential extension of LPE into account [31]. In the present study, all UE lesions had a concurrent diagnosis of LPE, and paraurethral endometriosis is frequently associated with LPE. This finding is consistent with that of Luca et al. [18]. However, this finding differed from earlier research, which showed an association with ovarian endometriomas in 52∼68 % of instances [12]. The present study showed that the average transverse axis of LPE for intrinsic UE was greater than or equal to 23 mm, and that for extrinsic UE was 20.5 mm.

Although this paper described the characteristic of thickening ureteric wall as a analytical criterion for the first time to predict intrinsic UE lesions and complex procedure, it was important to emphasise the limitations of the study. The main limitation of the present study was the size of study population, which was relatively small, due to the rarity of the disease. Second, as the present study was a one institution study, which the purpose was to perform all examinations with the same multidisciplinary team in order to have a homogeneous sample, avoiding possible bias from different operator's experience. Thirdly, the present study was retrospective nature

and future prospective studies should be performed to confirm the present results to establish an accurate cause-effect relationship between MRI characteristics and surgical procedure.

In conclusion, this paper showed that a dedicated analysis of MRI characteristics can be valuable for preoperatively diagnosing the pathological type of UE lesions for preoperative risk evaluation of performing complex procedures.

CRediT authorship contribution statement

Ling Rennan: Writing – original draft, Data curation, Formal analysis, Methodology, Writing – review & editing. **Shuo Yao:** Data curation, Methodology, Writing – original draft. **Hongtao Jin:** Data curation, Methodology, Writing – original draft. **Qinqin Yi:** Methodology. **Yan Wang:** Data curation, Methodology. **Yi Yang:** Writing – review & editing.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e34884.

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