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Original Article

Construction of a clinical predictive model for risk factors after laparoscopic surgery in patients with endometriosis based on pathologic characteristics

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Abstract: Objective: To investigate the correlation between preoperative pathologic characteristics and the risk of postoperative recurrence in endometriosis (EMs) patients, and to develop a clinical predictive model. Methods: A retrospective analysis was conducted on 164 EMs patients who underwent laparoscopic surgery between January 2022 and December 2023 at Peking University First Hospital Ningxia Women and Children's Hospital. Demographic and clinicopathologic data were collected, and patients were stratified by one-year recurrence status. Multivariable logistic regression identified independent recurrence risk factors, and a predictive nomogram was constructed. Model performance was evaluated using ROC curves, the Hosmer-Lemeshow goodness-of-fit test (HLGOF), calibration curves, and decision curve analysis. Results: Postoperative recurrence occurred in 46 patients (28%) within one year. Univariate analysis revealed associations between recurrence and factors including dysmenorrhea history, abortion, pathologic type, American Society for Reproductive Medicine (ASRM) stage, abnormal uterine bleeding, posterior fornix tender nodules, uterine enlargement, accessory area thickening, and delivery history (all $P<0.05$). Multivariate analysis confirmed that abortion (OR=1.31), ASRM stage ≥III (OR=1.03), abnormal uterine bleeding (OR=1.72), and posterior fornix tender nodules (OR=1.34) were independent predictors (all $P<0.05$). The nomogram (Logit (P)=$-3.30+1.31X_1+1.03X_2+1.72X_3+1.34X_4$) demonstrated an AUC of 0.802, with 71% sensitivity and 76% specificity. The HLGOF and calibration curves indicated that the predicted values were not significantly different from the observed values, showing good model fit (H-L, $P>0.05$). Conclusion: Preoperative pathologic features are significant predictors of recurrence after laparoscopic surgery for EMs. Monitoring these markers can help clinicians identify high-risk patients and provide more targeted treatment.

Keywords: Endometriosis, laparoscopic surgery, risk factors, line drawing model, recurrence

Introduction

Endometriosis (EMs) is a common chronic gynecologic disorder among reproductive-aged women, characterized by the ectopic implantation of endometrial-like glands and stroma. This estrogen-dependent condition manifests in debilitating symptoms, including chronic pelvic pain, dysmenorrhea, deep infiltrating lesions, and infertility, significantly worsening the quality of life of affected individuals [1, 2]. Epidemiological data indicate a concerning rise in the prevalence of EMs, currently estimated at 10-15%. Affected individuals frequently experience infertility, which affects women's physical and reproductive health [3, 4]. The pathogenesis of EMs remains incompletely understood, but evidence suggests a multifactorial etiology involving genetic predisposition, immune dysregulation, endocrine disruptors,

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chronic inflammation, and environmental interactions [5]. Common lesion sites include the ovaries, cervix, posterior fornix, uterosacral ligaments, rectum, vagina, and urinary system [6]. The location and depth of these lesions result in a range of symptoms, from dysmenorrhea and painful intercourse to chronic pelvic pain, infertility, and gastrointestinal issues. Lesions exhibit heterogeneity in size, shape, color, and location. The gold standard for diagnosing EMs is laparoscopic resection followed by histologic identification of endometrial epithelial and stromal cells. Clinically, EMs is categorized into Peritoneal Endometriosis, Ovarian Endometrioma, Deep Infiltrating Endometriosis, and other forms of EMs [7].

Historically, EMs treatment relied on medication and open surgery. Medications such as endometrin, progesterone, mifepristone, and danazol are commonly used [8, 9], but they are most effective in milder cases and have limited benefit on more severe forms. Surgical treatment includes traditional open surgery and laparoscopic surgery. Open surgery requires significant dissection under anesthesia, resulting in longer operation times, extended hospital stays, and slower recovery. With advances in medical technology, laparoscopic surgery has become a widely used treatment. It allows for clear visualization of pelvic anatomy, effective removal of diseased tissue, and reduced damage to healthy tissues, which improves patient outcomes [10]. However, EMs' characteristics often lead to recurrence after either procedure [11]. The recurrence rate after conservative surgery can reach as high as 50% within 5 years, and reoperation not only fails to reduce recurrence but may also further damage ovarian function [12]. In addition, lesion infiltration and pelvic adhesions increase the difficulty of secondary surgeries, leading to higher complication rates. Therefore, preventing recurrence after laparoscopic surgery is crucial.

This study aimed to analyze retrospectively the clinicopathologic characteristics of EMs patients before surgery and investigate their role in predicting the risk of recurrence within one year post-laparoscopy. The findings may provide new insights into using pathological characteristics for evaluating recurrence risk in EMs patients, allowing more timely adjustments to treatment and improved prevention strategies.

Methods and materials

Participants

This retrospective study included patients with EMs who underwent elective laparoscopic surgery at Peking University First Hospital Ningxia Women and Children's Hospital (Ningxia Hui Autonomous Region Maternal and Child Health Hospital) from January 2022 to December 2023. The patients were divided into recurrence (n=46) and non-recurrence (n=118) groups. The flowchart of this study is shown in **Figure 1**.

Inclusion criteria: (1) age 18-60 years; (2) diagnosis of EMs according to [13] (asymptomatic endometriosis detected by laparoscopy or open surgery, or ovarian endometriosis with pelvic pain detected by ultrasound or magnetic resonance imaging); (3) tolerated laparoscopic surgery treatment; (4) complete clinical information available.

Exclusion criteria: (1) no steroid use in the 6 months prior to surgery; (2) comorbidity with other pelvic inflammatory diseases or malignancies (e.g., ovarian cancer, endometrial cancer); (3) history of resection of ectopic endometriotic foci; (4) comorbidity with endocrine, immune, and metabolic disorders; and (5) presence of an intrauterine device (IUD; (6) receiving non-standardized adjuvant therapy (e.g., herbal enemas, immunosuppressants) after surgery.

This study was approved by the Ethics Committee of Peking University First Hospital Ningxia Women and Children's Hospital (Ningxia Hui Autonomous Region Maternal and Child Health Hospital).

Surgical modalities and treatments

All surgeries were performed by the same team of experienced gynecological laparoscopy specialists. Routine antibiotics were administered preoperatively, and the procedure was performed under general anesthesia in the supine position, with the lower limbs immobilized separately. A 1 cm incision was made at the umbilicus, through which a laparoscopic trocar was

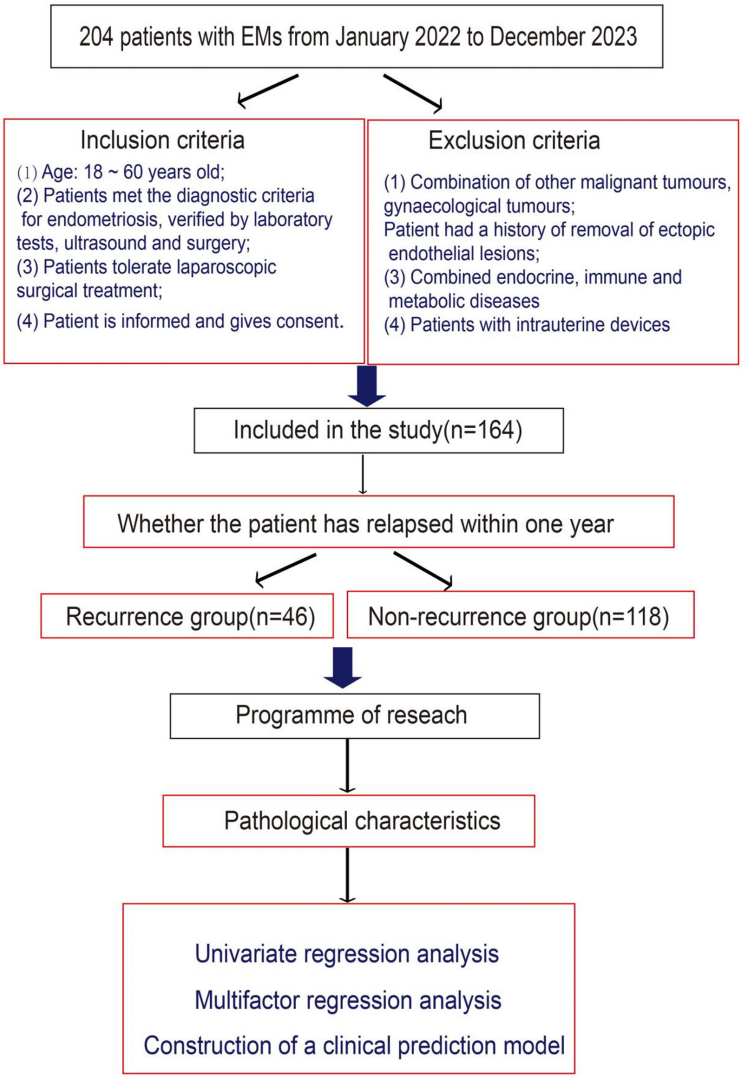

Figure 1. Flow chart of the study.

inserted. Carbon dioxide gas was introduced to establish a pneumoperitoneum, allowing for visualization. A thorough pelvic examination was performed to assess the stage of EMs and the extent of the lesions. Depending on lesion site and type, various surgical procedures-such as excision, stripping, cautery, and suturing-were performed to remove as much endometriotic tissue as possible while preserving normal pelvic anatomy and function. If the lesion involved the bladder wall, cystectomy with suturing was performed; if the ureter was affected, ureterotomy with anastomosis or stenting was required. If the lesion involved the bowel, surgical interventions such as bowel resection, segmentation, anastomosis, and suturing were carried out. The excised lesions were sent to the pathology department for histological examination to confirm the diagnosis. Postoperatively, patients received routine consolidation therapy with hormonal drugs and nutritional support according to their recovery progress.

General clinical data

General clinical data collected included age, body mass index (BMI), smoking history, drinking history, comorbid hypertension, and comorbid diabetes mellitus.

Data on pathological characteristics

The diagnostic pathology report for each patient was reviewed from the medical record system. The following data were recorded: age at menarche, age at first sexual intercourse, menstrual cycle regularity (regular or irregular), history of delivery, history of dysmenorrhea, history of abortion, pathologic type, American Society for Reproductive Medicine (ASRM) staging, abnormal uterine bleeding, hypogastralgia, posterior fornix tender nodules, pelvic mass, uterine enlargement, lesion diameter, tenderness, and accessory area thickening.

Uterine enlargement was defined as an anterior-posterior uterine diameter greater than 50 mm.

Dysmenorrhea was defined as abdominal cramps and pain before, during, or after menstruation, along with discomfort (e.g., lower back pain) that affected quality of life, excluding organic reproductive organ pathologies.

Follow-up

Follow-up results were extracted from outpatient and hospitalization records, as well as examination reports in the hospital's electronic

Table 1. Comparative general data

Group		Recurrence group (n=46)	Non-recurrence group (n=118)	t/x^2	P
n		46	118	-	-
Age		41.26±5.21	43.09±6.69	1.666	0.098
BMI		21.33±1.03	21.06±1.21	1.335	0.184
Smoking history	YES	9 (19.57)	21 (17.80)	0.069	0.792
	NO	37 (80.43)	97 (82.20)		
Drinking history	YES	18 (39.13)	39 (33.05)	0.540	0.463
	NO	28 (60.87)	79 (66.95)		
Combined diabetes	YES	11 (23.91)	19 (16.10)	1.351	0.245
	NO	35 (76.09)	99 (83.90)		
Combined high blood pressure	YES	13 (28.26)	22 (18.64)	1.823	0.177
	NO	22 (71.74)	96 (81.36)		

BMI: Body Mass Index.

medical record system. These included data on pregnancy, recurrence, and survival.

Diagnostic criteria for recurrence

Relapse was diagnosed based on the following criteria:

The reappearance or exacerbation of the lesion 3 months after the patient's postoperative remission.

The reappearance or exacerbation of positive signs during gynecological examination after the postoperative period, returning to the preoperative level.

The discovery of a new EMs lesion on ultrasound after the postoperative period.

Recurrence was confirmed by fulfillment of criteria (2) and (3), with or without (1) [14].

Clinical predictive modelling

Single-factor logistic regression analysis was used to identify recurrence risk factors. Variables with P<0.05 in the univariate analysis were included in the multivariable logistic regression model to construct a relapse risk prediction model, which was visualized as a graph. Variance inflation factor was used to assess multicollinearity between variables. The Area Under the Curve (AUC) was used to evaluate the predictive model's variability. Calibration curves and the Hosmer-Lemeshow goodness-of-fit test assessed model calibration. Decision Curve Analysis (DCA) was used to describe the net benefit across various risk probability thresholds based on predicted values. Additionally, the optimal cut-off value of the predictive model was determined using the Youden index, and the model's accuracy, sensitivity, and specificity were calculated.

Statistical analyses

Statistical analyses were performed using SPSS 19.0. Data that followed a normal distribution were expressed as mean ± standard deviation ($\bar{x}\pm s$) and comparisons between groups were made using independent samples t-tests. Counted data were expressed as percentages, with group differences compared using the chi-square test or Fisher's exact test. Variables with P<0.05 in the univariate logistic regression analysis were included in the multivariable logistic regression model. Variance inflation factors were calculated to assess potential multicollinearity. A *P*-value of <0.05 was considered significant.

Results

Comparison of general information

There were no significant differences between the two groups in terms of age, BMI, or general characteristics, including smoking history, drinking history, and comorbidities such as hypertension and diabetes mellitus (all *P*> 0.05). A detailed analysis of the data is presented in **Table 1**.

Table 2. Comparison of pathologic characteristics

Group			Recurrence group (n=46)	Non-recurrence group (n=118)	t/x^2	*P*
n			46	118		
Age of menarche			13.66±0.82	13.81±0.73	1.140	0.256
Age of first sexual intercourse			25.54±2.11	25.33±2.62	0.485	0.628
Length of menstruation (d)	<7		20 (43.48)	49 (41.53)	0.052	0.820
	≥7		26 (56.52)	69 (58.47)		
History of dysmenorrhea	YES		27 (58.70)	42 (35.59)	7.248	0.007
	NO		19 (41.30)	76 (64.41)		
Abortion	YES		26 (56.52)	33 (27.97)	11.717	<0.001
	NO		20 (43.48)	85 (72.03)		
Delivery history	YES		18 (39.13)	68 (57.63)	4.540	0.033
	NO		28 (60.87)	50 (42.38)		
Pathology type	Ovarian type	Left	16 (34.78)	53 (44.92)	1.394	0.238
		Right	10 (21.74)	29 (24.58)	0.147	0.701
		bilateral	6 (13.04)	22 (18.64)	0.733	0.392
	Peritoneal type		7 (15.22)	9 (7.63)	1.390	0.239
	Deep infiltration type		7 (15.22)	5 (4.24)	4.376	0.036
ASRM Staging	I-II		16 (34.78)	78 (66.10)	13.270	<0.001
	III-IV		30 (65.22)	40 (33.90)		
Diameter of the lesion (cm)	<6		25 (54.35)	92 (77.97)	9.030	<0.001
	≥6		21 (45.65)	26 (22.03)		
Abdominal	YES		18 (39.13)	40 (33.90)	0.396	0.529
	NO		28 (60.87)	78 (66.10)		
Abnormal uterine bleeding	YES		22 (47.83)	32 (27.12)	6.426	0.011
	NO		24 (52.17)	86 (72.88)		
Tenderness	YES		16 (34.78)	22 (18.64)	4.842	0.028
	NO		30 (65.22)	96 (81.36)		
Pelvic mass	YES		26 (56.52)	48 (40.68)	3.355	0.067
	NO		20 (43.48)	70 (59.32)		
Uterine enlargement	YES		19 (41.30)	30 (25.42)	3.984	0.046
	NO		27 (58.70)	88 (74.58)		
Posterior fornix tender nodule	YES		25 (54.35)	36 (30.51)	8.052	0.005
	NO		21 (45.65)	82 (69.49)		
Accessory area thickening	YES		19 (41.30)	27 (22.88)	5.566	0.018
	NO		27 (58.70)	91 (77.12)		

ASRM: American Society for Reproductive Medicine.

Comparison of pathologic characteristics

Compared with the non-recurrent group, the recurrent group had a significantly higher proportion of patients with a history of dysmenorrhea, history of abortion, deep infiltrative pathology, ASRM stage III-IV, lesion diameter >6 cm, abnormal uterine bleeding, tenderness, uterine enlargement, posterior fornix nodules, and thickening of the accessory area (all P<0.05). Additionally, the recurrent group had a lower proportion of patients with a history of childbirth compared to the non-recurrent group (*P*<0.05). No significant differences were observed in the age of menarche, age of first sexual intercourse, duration of menstruation, other types of pathology (e.g., ovarian or peritoneal), hypogastralgia, or pelvic mass (all *P*>0.05). The results are shown in **Table 2**.

Table 3. Details of impact factor assignments

Recurrence	YES	1
	NO	0
History of dysmenorrhea	YES	1
	NO	0
Abortion	YES	1
	NO	0
Pathology type	Non-deep infiltration type	0
	Deep infiltration type	1
ASRM Staging	I-II	0
	III-IV	1
Diameter of the lesion (cm)	<6	0
	≥6	1
Abnormal uterine bleeding	YES	1
	NO	0
Posterior fornix tender nodule	YES	1
	NO	0
Uterine enlargement	YES	1
	NO	0
Tenderness	YES	1
	NO	0
Accessory area thickening	YES	1
	NO	0

ASRM: American Society for Reproductive Medicine.

Univariate logistic regression analysis of factors affecting postoperative recurrence in patients with EMs

A univariate logistic univariate regression analysis was performed with postoperative recurrence of EMs as the dependent variable (1= recurrence, 0= no recurrence) and the variables with significant differences between the two groups as independent variables (refer to **Table 3** for the allocation table). The univariate analysis showed that the following factors were significantly associated with the recurrence of EMs after laparoscopic surgery: history of dysmenorrhea (P=0.019), history of abortion (*P*<0.001), deep infiltrative pathology (P=0.015), ASRM stage III-IV (P<0.001), abnormal uterine bleeding (*P*=0.011), posterior fornix tender nodule (*P*=0.002), tenderness (*P*= 0.028), uterine enlargement (*P*=0.046), accessory area thickening (*P*=0.036), and history of childbirth (*P*=0.033). These variables were statistically significant (all *P*<0.05) in relation to the recurrence rate after laparoscopic surgery in patients with EMs, as shown in **Table 4**.

Multivariable logistic regression analysis of factors affecting postoperative recurrence in patients with EMs

The dependent variable was postoperative recurrence (1= recurrence, 0= no recurrence), and variables with P<0.05 in the univariate logistic regression analysis were included as independent variables in the multivariable logistic regression model. The results revealed that the following factors were independent risk factors for recurrence after laparoscopic surgery.

History of abortion (OR=3.70, 95% CI=1.65-8.26, *P*=0.001); abnormal uterine bleeding (OR=2.79, 95% CI=1.23-6.32, *P*=0.014); ASRM stage III-IV (OR=5.60, 95% CI=2.39-13.08, *P*<0.001), and posterior fornix palpable nodule (OR=3.83, 95% CI=1.66-8.83, *P*=0.002).

All of these factors were statistically significant (all P<0.05), as shown in **Table 5**.

Modelling predictive equations for postoperative recurrence in patients with EMs

Based on the results of the multivariable logistic regression model, X_1, X_2, X_3, and X_4 represent the history of abortion, ASRM stage, abnormal uterine bleeding, and posterior fornix tender nodule, respectively. The risk function for recurrence after laparoscopic EMs is expressed as: Logit (P)=$-3.30+1.31X_1+1.03X_2+1.72X_3+1.34X_4$.

A larger value of the exponential part of the function corresponds to a higher risk index for recurrence. The prognostic index (PI) was calculated as: (PI)=$1.31X_1+1.03X_2+1.72X_3+1.34X_4$.

A higher PI value indicates a higher risk of recurrence.

Nomogram model for predicting postoperative recurrence in patients with EMs

Using R (version 4.4.1), a nomogram model was constructed to predict early postoperative

Table 4. Univariate logistic regression analysis

Variable		β	S.E	Z	*P*	OR (95% CI)
History of dysmenorrhea	0					1.00 (Reference)
	1	0.82	0.35	2.32	0.019	2.27 (1.13-4.53)
Abortion	0					1.00 (Reference)
	1	1.26	0.36	3.47	<0.001	3.51 (1.73-7.14)
Pathology type	0					1.00 (Reference)
	1	1.40	0.61	2.28	0.015	4.06 (1.22-13.52)
ASRM Staging	0					1.00 (Reference)
	1	1.30	0.37	3.55	<0.001	3.66 (1.79-7.49)
Abnormal uterine bleeding	0					1.00 (Reference)
	1	0.90	0.36	2.50	0.011	2.46 (1.22-4.99)
Tenderness	0					1.00 (Reference)
	1	0.84	0.39	2.17	0.028	2.33 (1.08-4.99)
Uterine enlargement	0					1.00 (Reference)
	1	0.72	0.37	1.98	0.046	2.06 (1.01-4.23)
Posterior fornix tender nodule	0					1.00 (Reference)
	1	1.08	0.36	3.00	0.002	2.94 (1.46-5.95)
Accessory area thickening	0					1.00 (Reference)
	1	0.77	0.37	2.07	0.036	2.17 (1.04-4.50)
Delivery history	0					1.00 (Reference)
	1	-0.75	0.35	-2.11	0.033	0.47 (0.24-0.95)
Diameter of the lesion (cm)	0					1.00 (Reference)
	1	0.49	0.35	1.39	0.162	

ASRM: American Society for Reproductive Medicine.

Table 5. Multivariate Logistic regression analysis

Variable		β	S.E	Z	*P*	OR (95% CI)	Variance inflation factor
Abortion	0					1.00 (Reference)	1.414
	1	1.31	0.41	3.19	0.001	3.70 (1.65-8.26)	
Abnormal uterine bleeding	0					1.00 (Reference)	1.127
	1	1.03	0.42	2.45	0.014	2.79 (1.23-6.32)	
ASRM Staging	0					1.00 (Reference)	1.109
	1	1.72	0.43	3.98	<0.001	5.60 (2.39-13.08)	
Posterior fornix tender nodule	0					1.00 (Reference)	1.084
	1	1.34	0.43	3.15	0.002	3.83 (1.66-8.83)	

ASRM: American Society for Reproductive Medicine.

recurrence in EMs patients after laparoscopy, based on the multivariable outcome analysis. Each indicator corresponds to a line segment, with the endpoints reflecting the classification of the indicators. The left side of the model represents non-risk or protective factors, while the right side represents risk factors. The scores for each factor were assigned as follows.

History of abortion: 76 points; Abnormal uterine bleeding: 60 points; ASRM stage III-IV: 100 points; Posterior fornix tenderness: 78 points.

The total score was the sum of the scores for each factor, and the corresponding point on the total score axis was used to predict the probability of postoperative recurrence. The higher the total score, the higher the risk of recurrence, as shown in **Figure 2**.

Model evaluation

ROC curves were plotted to assess the predictive power of the nomogram model (**Figure 3**). The area under the curve (AUC) for this regres-

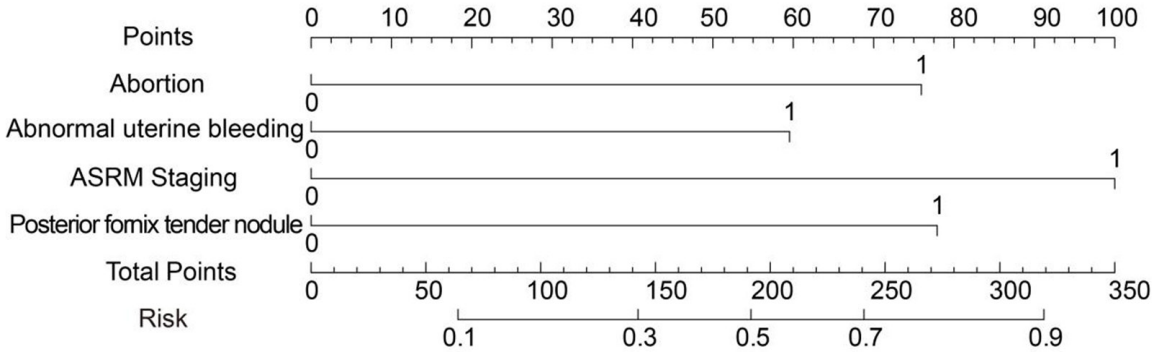

Figure 2. Clinical predictive model for predicting the risk of postoperative recurrence in patients with endometriosis. ASRM: American Society for Reproductive Medicine.

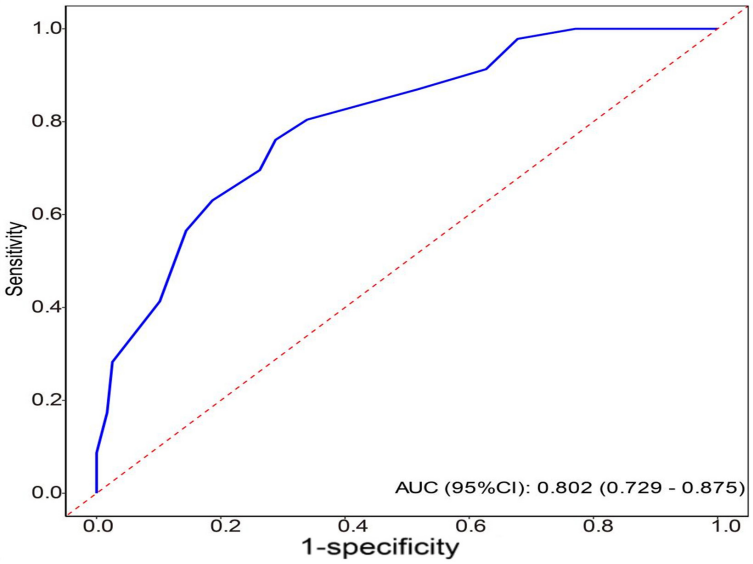

Figure 3. Evaluation of clinical predictive model's-ROC curve analysis. Abbreviations: ROC-Receiver Operating Characteristic.

sion equation was 0.802 (95% CI=0.729-0.875), indicating good discrimination. The Hosmer-Lemeshow goodness-of-fit test and calibration curve showed no significant difference between the predicted and measured values, indicating that the model was well fitted (H-L, P>0.05). The calibration curve confirmed that the model effectively predicted postoperative recurrence in patients with endometriosis (**Figure 4**). The DCA showed that the net benefits of the model were comparable within a specific range of thresholds, as seen in **Figure 5**. At the optimal threshold, the model demonstrated an accuracy of 0.73 (95% CI: 0.65-0.79), a sensitivity of 0.71 (95% CI: 0.63-0.79), and a specificity of 0.76 (95% CI: 0.64-0.88), as shown in **Table 4**.

Discussion

Endometriosis (EMs) is an estrogen-dependent gynecologic disorder prevalent among reproductive-aged women, characterized by the ectopic proliferation of endometrial-like glands and stroma beyond the uterine cavity. This abnormal tissue growth induces chronic inflammatory responses and results in debilitating clinical symptoms, including associated lesions [15]. EMs can affect any part of the body, but the ovaries, ovarian fossa, and uterosacral ligaments are the most common sites. The incidence of EMs is second only to other gynecologic inflammatory diseases and fibroids [16]. Incomplete statistics suggest that EMs affects approximately 10% to 15% of women of reproductive age worldwide. Although histologically benign, ectopic endometrium shares several characteristics with tumors, including extensive implantation, growth, infiltration, fibrous adhesion to surrounding tissues, and a tendency for recurrence. This leads to symptoms such as dysmenorrhea, pelvic pain, difficulty with sexual intercourse, and infertility, worsening social, occupational, and psychological well-being [17]. Studies have shown that laparoscopic treatment yields relatively good outcomes for EMs patients, making it a preferred conservative surgical approach. However, recurrence after surgery remains common [14, 18]. Reducing the risk of early recurrence and

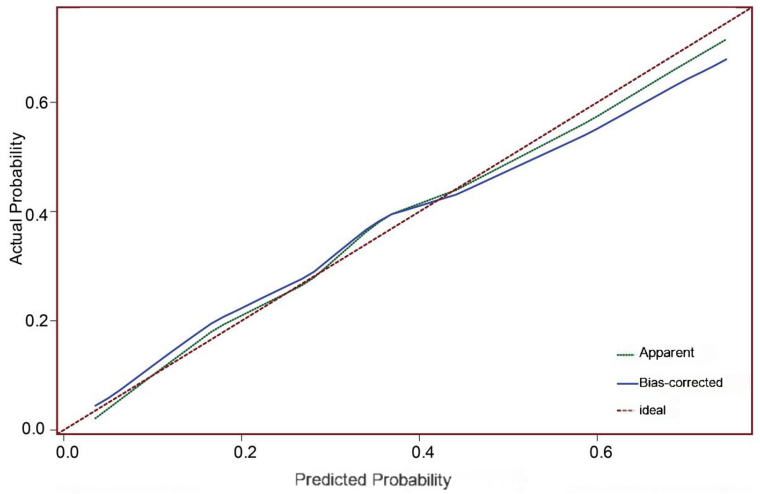

Figure 4. Evaluation of clinical predictive model's-Calibration curve and Hosmer-Lemeshow goodness of fit test.

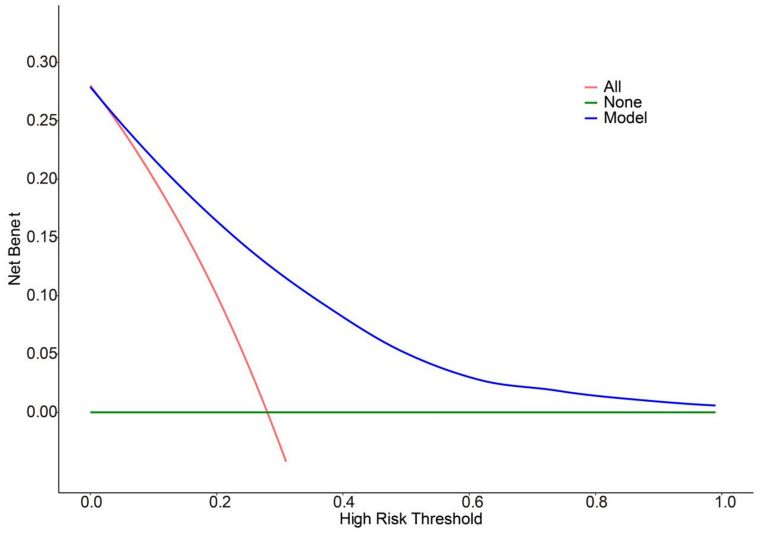

Figure 5. Evaluation of clinical predictive model's-DCA curve. Abbreviations: DCA-Decision Curve Analysis.

improving prognosis remain critical areas of ongoing research. This study aimed to investigate the relationship between patients' pathological characteristics at the time of onset and the risk of postoperative recurrence. It analyzed risk factors for postoperative recurrence after laparoscopy in EMs patients and constructed a prediction model using nomogram analysis to identify high-risk groups, providing a basis for clinical prevention of recurrence.

Univariate regression analysis revealed significant differences in several clinicopathologic characteristics between patients in the recurrence and non-recurrence groups, including history of dysmenorrhea, history of abortion, pathologic type, ASRM stage III-IV, abnormal uterine bleeding, posterior fornix tender nodule, tenderness, uterine enlargement, accessory area thickening, and history of childbirth. These results suggest a relationship between pathologic status and the occurrence of postoperative recurrence. Multivariate logistic regression analysis showed that history of abortion, ASRM staging, abnormal uterine bleeding, and palpable nodules in the posterior fornix were independent risk factors for recurrence after surgery. The following explanations may account for these findings.

(1) The impact of a history of abortion on recurrence is likely due to hormonal changes, altered immune function, and effects on the intrauterine environment. During pregnancy, estrogen levels are elevated, but after abortion, especially spontaneous abortion, estrogen levels drop dramatically. This hormonal instability may promote the recurrence of EMs [19]. Some studies suggest that lower estrogen levels might inhibit ectopic endometrium growth, but hormonal fluctuations after abortion, especially during recovery, may encourage the growth and recurrence of residual tissue [20]. Furthermore, after an abortion, the female immune system may undergo changes that affect the body's tolerance to ectopic endometrial tissue, potentially triggering a pro-inflammatory response that promotes tissue growth [21-23]. Additionally, the regeneration and repair of the endometrium after abortion may affect the growth of ectopic foci, especially in areas like the ovaries, fallopian tubes, and pelvic peritoneum, where EMs typically occur.

(2) ASRM staging is a qualitative and quantitative method of grading EMs based on lesion extent, location, depth, and involvement of associated anatomical structures. The relatively low recurrence rate after laparoscopic surgery in stage I-II patients is due to the fact that mild lesions generally involve fewer ectopic areas, which are more confined and less likely to cause extensive pathologic changes or adhesions [24]. In these patients, laparoscopic surgery is usually effective in thoroughly removing the lesions, and postoperative medications help inhibit recurrence. However, for stage III-IV patients, lesions may involve larger cysts or severe adhesions, making it difficult to completely remove all ectopic foci during surgery. Residual tissue may regenerate or recur due to hormonal fluctuations, potentially leading to long-term chronic pain or infertility [11, 25].

(3) The ectopic endometrial tissue in EMs proliferates and sheds during the menstrual cycle. However, due to its abnormal location, it may lead to local hematoma, adhesion, or tearing of the ectopic foci, potentially resulting in abnormal bleeding. This is particularly common when the lesions involve the ovaries, uterus, fallopian tubes, or pelvic peritoneum, where the bleeding may increase in severity and frequency. Such bleeding is a common clinical manifestation of EMs and a warning sign of recurrence after surgery [3, 26]. Studies suggest that if hormone levels are not well-controlled post-surgery, the ectopic endometrial tissue may proliferate and shed again, leading to symptom recurrence. Additionally, adhesions are a common complication of EMs, especially in severe cases. The formation of adhesions not only affects fertility but also leads to irregular uterine bleeding or prolonged menstrual periods. Thus, abnormal bleeding after surgery may indicate adhesion formation or lesion recurrence.

(4) EMs can cause various types of pain, including dysmenorrhea, non-menstrual abdominal pain, pain during intercourse, and pain during bowel movements. Some researchers have noted that palpable nodules in the posterior fornix result from the invasion of the rectovaginal septum and uterosacral ligaments by endometriotic lesions [27]. During menstruation, these deep nodules become congested and edematous. In severe cases, they may lead to the closure of the uterorectal fossa, compressing sensory nerves at the lesion site, causing tenderness in the posterior fornix. Fertility-preserving surgery may struggle to remove such lesions, and the presence of palpable nodules in the posterior fornix may indicate that EMs has affected the endocrine system, resulting in symptoms such as early or late menstruation, or changes in menstrual flow [28, 29]. In this patient group, the risk of recurrence is significantly increased after surgery due to the complexity of the lesions, leading to a higher recurrence rate in the postoperative period.

With the advancement of biostatistical methods and increasing reliance on statistical techniques in clinical research, statistical predictive models are now widely used across various aspects of clinical practice. The challenge is to integrate clinical research needs with statistical methods to create prediction models that meet clinical requirements, minimizing the risk of disease recurrence or death while reducing unnecessary exposure. Among these predictive models, line-plot models are gaining popularity among medical professionals for their unique advantages [30, 31].

This study has certain limitations. First, as a single-center retrospective study, it did not use data from other hospitals as a validation cohort, which may introduce selection bias. Additionally, due to time constraints, this study only investigated recurrence within one year after discharge. Future studies should expand the scope of case selection and extend the follow-up duration to further improve and validate the model.

In conclusion, a history of miscarriage, ASRM staging, abnormal uterine bleeding, and palpable nodules in the posterior fornix are independent risk factors for recurrence after laparoscopic surgery in patients with endometriosis. The line-plot model developed also demonstrates good predictive ability for postoperative recurrence risk and can be used for preoperative assessment of recurrence risk in these patients.

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Disclosure of conflict of interest

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