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Construction and validation of a prediction model for postoperative recurrence risk of cervical high-risk lesions using nomogram analysis

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Abstract

Patients with cervical high-risk lesions face a heightened risk of recurrence following cervical conization, making early prediction of recurrence essential for effective treatment and follow-up. This retrospective cohort study aimed to develop a recurrence risk prediction model using clinical factors to enhance prediction accuracy and guide clinical decisions. The study included 120 female patients undergoing their first cervical conization with positive surgical margins. Clinical data such as age, human papilloma virus (HPV) typing, surgical margin status, colposcopy results, and postoperative treatments were analyzed. Univariate and multivariate logistic regression identified age ≥ 45 years, HPV 16/18 infection, and positive surgical margins at the internal or external os as independent predictors of recurrence. A nomogram model was constructed and validated externally, achieving 90.3% accuracy in predicting recurrence in an additional 31 patients. Decision curve analysis confirmed the model's higher net benefit compared to single-factor predictions. We conclude that the recurrence risk prediction model, based on age, HPV typing, and surgical margin status, offers high accuracy and clinical utility, supporting individualized patient management and precise treatment planning. *(Afr J Reprod Health 2025; 29 [6]: 94-107).*

Keywords: cervical high-risk lesions; recurrence prediction; nomogram; HPV typing; surgical margins

Résumé

Les patientes présentant des lésions cervicales à haut risque sont exposées à un risque accru de récidive après une conisation cervicale, ce qui rend la prédiction précoce de la récidive essentielle pour un traitement et un suivi efficaces. Cette étude de cohorte rétrospective visait à développer un modèle de prédiction du risque de récidive basé sur des facteurs cliniques afin d'améliorer la précision de la prédiction et de guider les décisions cliniques. L'étude a inclus 120 patientes ayant subi leur première conisation cervicale avec des marges chirurgicales positives. Les données cliniques telles que l'âge, le typage du papillomavirus humain (HPV), l'état des marges chirurgicales, les résultats de la colposcopie et les traitements postopératoires ont été analysés. Les analyses de régression logistique univariée et multivariée ont identifié l'âge ≥ 45 ans, l'infection par le HPV 16/18 et la positivité des marges chirurgicales au niveau de l'orifice interne ou externe comme des facteurs prédictifs indépendants de récidive. Un modèle de nomogramme a été construit et validé de manière externe, atteignant une précision de 90,3 % dans la prédiction de la récidive chez 31 patientes supplémentaires. L'analyse des courbes de décision a confirmé que le modèle offrait un bénéfice net supérieur par rapport aux prédictions fondées sur un seul facteur. Nous concluons que ce modèle de prédiction du risque de récidive, fondé sur l'âge, le typage HPV et l'état des marges chirurgicales, présente une grande précision et une utilité clinique, favorisant une prise en charge individualisée des patientes et une planification thérapeutique plus précise. *(Afr J Reprod Health 2025; 29 [6]: 94-107).*

Mots-clés: lésions cervicales à haut risque; prédiction de récidive; nomogramme; typage HPV; marges chirurgicales

Introduction

Cervical intraepithelial neoplasia (CIN) is a kind of cervical cancer related precancerous lesions. Based on the severity of the lesion, CIN is divided into three grades: CIN I, CIN II, and CIN III. According to the Lower Anogenital Squamous Terminology system, CIN I is classified as low-grade squamous intraepithelial lesion (LSIL), while CIN II and CIN III are classified as high-grade squamous intraepithelial lesion (HSIL).[1-4] HSIL is widely regarded as a precancerous lesion of cervical cancer and an important warning sign for its treatment. If left untreated, CIN3 has a probability of 30%-50%

to progress to cervical invasive cancer within two to five years, making timely diagnosis and effective treatment of HSIL a key component of women's health management.[5-7] With the widespread infection of HPV, especially high-risk HPV types (such as HPV 16 and 18), the incidence of cervical lesions has been increasing year by year, and HSIL has become one of the major public health challenges facing women's health globally.[8,9] HPV infection is the main cause of cervical cancer, and high-risk HPV infection is closely related to the occurrence and progression of CIN. In particular, HPV 16 and HPV 18 are considered the main oncogenic types of viruses causing cervical cancer. These viruses induce gene mutations and carcinogenesis in cervical cells through infection.[10,11] Therefore, the widespread prevalence of HPV has made HSIL a "warning signal" for cervical cancer. If not treated in time, it may lead to the occurrence of cervical cancer, thereby increasing patient mortality and significantly reducing quality of life, causing a heavy social and economic burden.

In clinical practice, HSIL is usually treated by cervical conization [such as cold knife conization (CKC) or LEEP surgery]. These surgeries aim to cure the lesion by resecting the affected area of the cervix and prevent its further progression to cervical cancer.[10,11] However, despite cervical conization being the standard treatment for HSIL, this method is not omnipotent. On the one hand, due to the complex anatomical structure of the cervix, some patients may have positive surgical margins after surgery, meaning that the lesion has not been completely resected, increasing the risk of recurrence.[14,15] On the other hand, factors such as postoperative persistent HPV infection, patient immune function status, and the standardization of follow-up may also affect the prognosis of the disease. Therefore, although cervical conization can significantly reduce the incidence of cervical cancer, long-term and standardized follow-up is still required to detect and manage possible recurrences or progressions in a timely manner.[16,17] Failure to treat HSIL in time or incomplete treatment may lead to its progression to cervical cancer, causing serious harm to the patient's health, including pain, bleeding, dysuria, weight loss, anemia, and other symptoms. Moreover, as the cancer progresses, the patient's survival may also be threatened.[16] In addition, radiotherapy and chemotherapy, which are often required in the treatment of cervical cancer, are usually accompanied by severe side effects that greatly reduce the patient's quality of life. Therefore, effective treatment of HSIL patients, postoperative monitoring, and recurrence prediction are of great importance. In addition to conventional cervical conization, identifying high-risk patients for recurrence or progression at an early stage and developing individualized treatment and follow-up plans will play an important role in the management of cervical lesions.[19]

Currently, there is a lack of reliable recurrence prediction tool in clinical practice that can help doctors effectively assess the likelihood of recurrence in patients and guide subsequent treatment decisions. Early warning of recurrence is crucial for improving patient prognosis. By in-depth analysis of potential factors affecting recurrence and constructing a precise prediction model, more individualized management plans can be provided for patients to reduce the occurrence of recurrence and improve treatment outcomes. Therefore, this article aims to explore the key factors affecting postoperative recurrence in HSIL patients based on clinical data, with the more specific objective to construct an effective recurrence risk prediction model. It is hoped that the establishment of this model will provide a new tool for clinical practice to help doctors better manage postoperative care and improve patients' long-term prognosis.

Methods

Study design and patient selection

The study was a retrospective cohort study which was approved by the Ethics Committee of the Fifth Peoples' Hospital of Jinan. The subjects were female patients who received treatment for HSIL in the Department of Obstetrics and Gynecology at the Fifth People's Hospital of Jinan from January 1, 2012, to May 31, 2021. All patients were undergoing their first cervical conization (including CKC or LEEP), while postoperative pathology showed positive margins (cervical lesion ≤1 mm from the margin or involvement of the external or internal os of the margin). A total of 163 patients met the inclusion criteria. Forty-three patients were excluded for the following reasons: previous

cervical conization; conization after diagnosis of microinvasive cancer; postoperative pathology report showing invasive cancer; presence of diseases affecting the immune system or other malignancies; incomplete clinical data. Ultimately, 120 patients were included in the study.

The medical records of all patients, including pathology reports, were processed through retrospective analysis, and data were collected via the hospital's electronic medical record system. During the data analysis process, patient's privacy was strictly protected. Since the study only used archived historical clinical data, informed consent was not required.

Collection and screening of clinical data

Clinical data of the 120 patients were retrospectively collected and analyzed. All patients underwent cytological examination under the Bethesda system and high-risk HPV DNA testing using the Roche Cobas 4800 HPV DNA test system[20,21]. In addition, all patients underwent colposcopy, and biopsies were performed on those with suspicious lesions detected under colposcopy.

After surgery, patients with positive margins were informed that their postoperative lesions were close to or involved the margin, and subsequent treatment plans were formulated based on specific conditions. Clinicians and patients jointly decided whether to undergo re-conization, hysterectomy, or other treatments based on the patient's age, desire for childbirth, ability to accept follow-up, and the presence of other gynecological diseases. Patients were regularly followed up at 3, 6, 12, 18, and 24 months postoperatively, with annual follow-ups continuing until five years after surgery. Cytological examination and HPV testing were performed at each follow-up. If the cytological or HPV test results were positive, colposcopy was further conducted, and biopsies were taken from suspicious lesions to assess the recurrence of CIN.

Assessment of factors influencing recurrence

The assessment of recurrence was based on the following aspects: cytological examination, HPV test results, colposcopy, and further biopsy results during postoperative follow-up. If patients had positive cytology or HPV test results and suspicious lesions were detected by colposcopy, biopsies were performed to further confirm the recurrence of CIN. Through retrospective analysis of different recurrence cases, the study explored the potential impact of the following factors on recurrence.

(1) Patient age: Women of different age groups may face different recurrence risks, especially between menopausal and young patients.

(2) HPV infection status: High-risk HPV infection is significantly associated with the recurrence of cervical lesions, and the persistence of HPV DNA may increase the risk of recurrence.

(3) Immune status: The immune function of patients may affect the recurrence of lesions, with a higher recurrence risk in immunosuppressed patients.

(4) Pathological characteristics: Factors such as the type of lesion and the status of positive margins in postoperative pathology reports may be predictive of recurrence.

(5) Fertility desires and follow-up status: Whether patients plan to have children and whether they can accept regular follow-up are also important factors in assessing recurrence risk.

Analysis of factors influencing recurrence and construction of scoring system

To explore factors influencing recurrence and construct a predictive scoring system for recurrence based on these factors, univariate analysis was first conducted to screen for potential factors influencing recurrence. The chi-square test was used in univariate analysis to identify clinical factors significantly related to recurrence rate. Factors showing significant differences in univariate analysis were further subjected to multivariate logistic regression analysis to assess the independent contribution of each factor to recurrence risk. The regression model determined the weight of each influencing factor based on statistical results, thereby constructing a predictive scoring system for recurrence. This scoring system, based on the weighted scores of multiple clinical variables, quantifies the recurrence risk for different patients and is presented in the form of a nomogram.

Scoring system and recurrence risk assessment

Based on the results of multivariate analysis, a predictive scoring system for recurrence was

constructed. Each clinical characteristic of the patient was assigned a corresponding score according to the results of model construction. The total score, accumulated from these individual scores, was used to assess the patient's risk of recurrence. The scoring system visualized the weight of each variable through a nomogram, thereby helping clinicians predict the recurrence risk based on the patient's clinical characteristics.

External validation and model validation

To assess the external validity of the constructed recurrence prediction scoring system, partial clinical data of the patients were obtained, and the scoring system was used to predict recurrence. The predictive accuracy of the model in clinical practice was assessed. External validation helped evaluate the applicability and stability of the scoring system in different patient populations.

DCA

Decision curve analysis (DCA)was used to evaluate the clinical value of the recurrence scoring system. The study employed DCA to assess the net benefit of the predictive scoring system compared to single clinical indicators in predicting recurrence. DCA was able to quantify the practical application value of the predictive tool in different clinical scenarios, thereby demonstrating the model's clinical utility.

Statistical analysis

Statistical analyses of all data were conducted using SPSS 24.0 (SPSS Inc., Chicago, IL, USA) and the R language (version 3.5.2; R Foundation for Statistical Computing, www.r-project.org). The "rms" and "rmda" packages were used for data processing and model construction. To evaluate clinical factors influencing recurrence, univariate chi-square tests were initially performed to compare background factors among different patient groups and to determine the correlation of each factor with lesion recurrence. In the univariate analysis, variables with P-values less than 0.05 were included in the subsequent multivariate logistic regression analysis.

Ethical consideration

The research team strictly adhered to ethical principles, ensuring the protection of patients' privacy and personal information, with all patients providing informed consent to participate in this study. To safeguard patient privacy, anonymized data were used in this study to prevent the disclosure of personal identity information. Furthermore, all data collected in this study were strictly for research purposes and were not used for any commercial purposes. All patients involved in this study signed an informed consent form prior to participation, which clearly outlined the study's purpose, methods, potential risks, and their rights, including the right to withdraw from the study at any time. This study was approved by the Ethics Committee of the Fifth People's Hospital of Jinan, approval number 25-5-07

Results

Univariate analysis

The core purpose of univariate analysis was to compare differences in recurrence rates among various factors and to assess whether these differences were statistically significant. Factors with significant differences in recurrence rates were retained and included in the subsequent multivariate analysis to further explore their roles in recurrence prediction and ultimately establish a predictive scoring system for recurrence. The results of the univariate analysis in this article are shown in Table 1. The following factors were found to have significant differences in recurrence rates.

Patients over the age of 45 had a significantly higher recurrence rate (70.6%) compared to those under 45 (P = 0). Patients with inadequate colposcopy had a higher recurrence rate (66.7%) than those with adequate colposcopy (35.4%) (P = 0.005). Postmenopausal patients had a higher recurrence rate (62.0%) compared to non-postmenopausal patients (37.8%) (P = 0.042). Patients infected with HPV 16/18 had a higher recurrence rate (59.0%) compared to those with other types of HPV infection (23.7%) (P = 0). Patients with margins at the internal or external os had a higher recurrence rate, especially those with margins at the internal os, with a recurrence rate of 72.7% (P = 0). Patients who underwent reoperation had a higher recurrence rate (60.0%) compared to those who received close follow-up (34.1%) (P = 0.009).

Table 1: Results of univariate analysis

		Status		Incidence rate	χ^2	*P*
		Healing	Relapse			
Age	< 45 years old	60	26	30.2%	16.327	0
	≥45 years old	10	24	70.6%		
Colposcopy image	Normal LSIL	12	4	25.0%	1.984	0.371
	Normal HSIL	54	40	42.6%		
Colposcopy detection	Adequate	62	34	35.4%	7.714	0.005
	Inadequate	8	16	66.7%		
Menopausal status	Non-menopause	61	37	37.7%	4.140	0.042
	Menopause	8	13	61.9%		
HPV typing	HPV 16/18	25	36	59.0%	15.365	0
	Other	45	14	23.7%		
Cytology	≤ LSIL	37	26	41.3%	.009	0.926
	> LSIL	33	24	42.1%		
Pathology after conization	CIN2	17	8	32.0%	1.214	0.271
	CIN3	53	42	44.2%		
Postoperative pathology involving the glands	Yes	55	39	41.5%	.006	0.94
	No	15	11	42.3%		
Margin	Ectocervical	62	24	27.9%	24.003	0
	Endocervical	6	16	72.7%		
	Both margins	2	10	83.3%		
Clinical management	Close follow-up	56	29	34.1%	6.833	0.009
	Reoperation	14	21	60.0%		

At the significance level of 0.05, the differences in recurrence rates for these factors were all statistically significant. Therefore, these factors were further explored in the subsequent multivariate analysis to assess their combined impact on recurrence prediction.

Multivariate analysis

After the univariate analysis identified four factors with significant differences in recurrence rates, binary logistic regression was employed for multivariate analysis to further assess the independent impact of these factors on recurrence. In Table 2, patients aged ≥45 years had a significantly increased risk of recurrence (OR = 4.5, 95% CI = 1.1-18.0), with approximately 4.5 times the risk of recurrence compared to patients under 45 years old (P = 0.03). Although patients with inadequate colposcopy had a higher recurrence rate, this factor did not reach statistical significance in the multivariate analysis (P = 0.6), with an OR of 1.4 (95% CI = 0.4-5.6), indicating that the adequacy of colposcopy had a minor impact on recurrence prediction. Patients infected with HPV 16/18 had a significantly increased risk of recurrence (OR = 3.4, 95% CI = 1.4-8.3) (P = 0.0), with about 3.4 times the risk compared to those infected with other HPV types. Patients with margins at the internal os had a significantly increased risk of recurrence (OR = 5.5, 95% CI = 1.8-16.9) (P = 0.0), with a fivefold increase in risk compared to those with margins at the external os. Patients with margins involving both the internal and external os had an even higher risk of recurrence (OR = 7.3, 95% CI = 1.3-42.6) (P = 0.0).

Table 2: Results of multivariate analysis

Variable	B	Standard Error	Wald	Degrees of Freedom	Significance	OR	95% CI for OR	Lower Limit
Age ≥45 years old	1.5	0.7	4.5	1	0	4.5	1.1	18
Age <45 years old	0	0	0	1	1	1	1	1
Colposcopy Inadequate	0.3	0.7	0.2	1	1.6	1.4	0.4	5.6
Colposcopy Adequate	0	0	0	1	1	1	1	1
HPV Typing HPV 16/18	1.2	0.5	6.8	1	0	3.4	1.4	8.3
HPV Typing Other	0	0	0	1	1	1	1	1
Margin Endocervical	1.7	0.6	8.7	1	0	5.5	1.8	16.9
Margin Both margins	2	0.9	4.9	1	0	7.3	1.3	42.6
Margin Ectocervical	0	0	0	1	1	1	1	1
Clinical Management Reoperation	0.3	0.6	0.3	1	1.6	1.3	0.4	4.2
Clinical Management Close follow-up	0	0	0	1	1	1	1	1
Menopausal Status Menopause	-0.5	0.8	0.5	1	0.5	0.6	0.1	2.7
Menopausal Status Non-menopause	0	0	0	1	1	1	1	1
Constant	-2	0.4	22.7	1	0	0.1	0.1	0.1

There was no significant difference in recurrence risk between patients who underwent reoperation and those who received close follow-up (OR = 1.3, 95% CI = 0.4-4.2, P = 0.6), indicating that clinical management had a minor independent impact on recurrence. Menopausal status did not reach significance in the multivariate analysis (P = 0.5), although the risk of recurrence was slightly lower in postmenopausal patients (OR = 0.6, 95% CI = 0.1-2.7). Thus, age, HPV typing, status of surgical margins, and clinical management were significant factors influencing recurrence, while the adequacy of colposcopy and menopausal status did not significantly predict recurrence risk in the multivariate analysis. Tab2

Establishment of the predictive scoring system

Based on the results of the multivariate analysis mentioned above, age, HPV typing, and status of surgical margins were identified as the three factors that could independently influence recurrence. Subsequently, a predictive scoring system for recurrence was established using nomogram analysis based on these three independent factors (Figure 1).

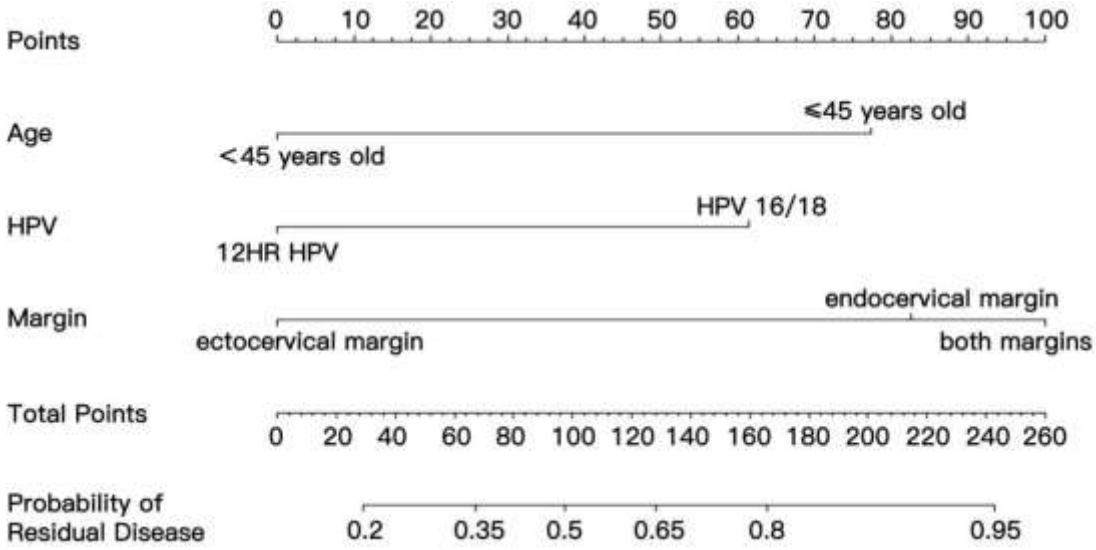

Figure 1: Nomogram for predictive scoring system of recurrence

Table 3: Scoring system corresponding to the nomogram

		Scoring
Age	< 45 years old	0
	≥45 years old	77
HPV typing	HPV 16/18	61
	Other	0
Margin	Endocervical margin	83
	Both margins	100
	Ectocervical margin	0

The corresponding scoring system for the above nomogram is shown in Table 3.

For example, if a patient is 40 years old, has HPV typing of HPV 16/18, and has both margins, then the recurrence score for this patient would be calculated as follows: 0 (age <45 years) + 61 (HPV 16/18) + 100 (both margins) = 161. Subsequently, the score of 153 was entered into the above nomogram, and the corresponding recurrence rate was found according to the scale (Figure 2). The term MARSI refers to medication-related acute skin injury, which denotes skin damage caused by pharmaceutical treatments. Specifically, certain medications or therapies may irritate, damage, or induce adverse reactions in the skin. The incidence of MARSI refers to the frequency or rate of occurrence of medication-related acute skin injury within a specific population or study group. This incidence is used to assess the prevalence of drug-related skin damage, particularly in clinical settings where medical treatments or procedures may lead to skin exposure to certain chemicals, adhesive products, or topical medications.

It could be observed that a patient with a score of 161 had a possibility of recurrence close to 80%. With 50% as the cutoff point, it could be accurately determined that the patient would experience recurrence. The correspondence between the total score and the recurrence rate is shown in Table 4, from which it could be known that with 50% as the cutoff point, a patient's score greater than 98 indicated that the patient would experience recurrence.

Finally, the accuracy of the nomogram for predicting recurrence was evaluated with a cindex of 80.7%, and the 95% CI for the cindex was 72.6% to 88.9%, indicating a highly accurate prediction. To further validate the accuracy of the nomogram, a calibration plot was constructed to assess the prediction accuracy (Figure 3). The diagonal line represents the perfect agreement between predicted and actual values, while the black solid line indicates the prediction results. The solid line is close to the diagonal, further demonstrating the accuracy of the prediction results.

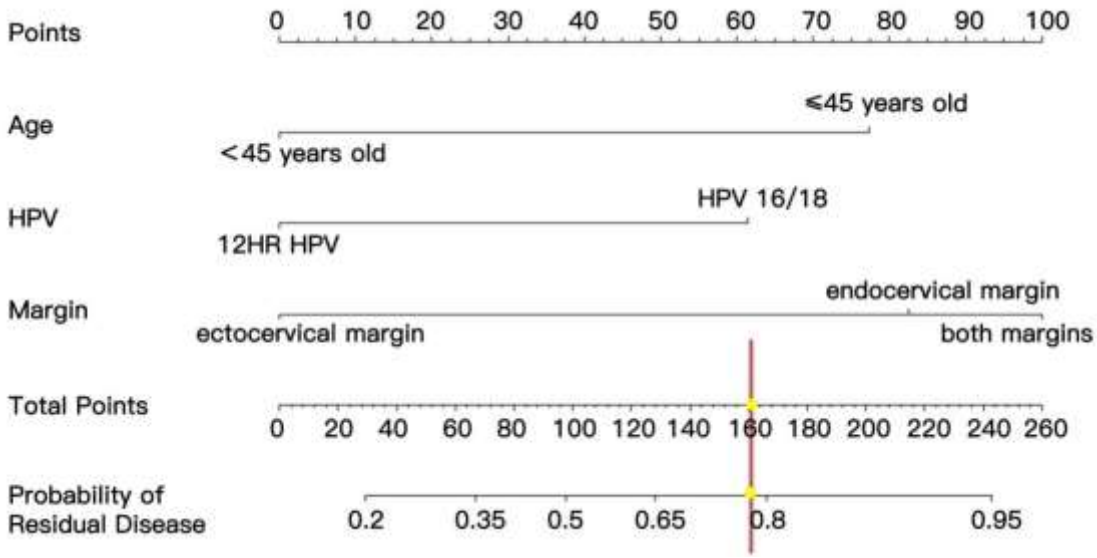

Figure 2: Nomogram for MARSI incidence rate

Table 4 : Correspondence between total score and recurrence rate

Incidence of MARSI	MARSI occurrence scoring
15.00%	12
20.00%	29
25.00%	43
30.00%	56
35.00%	67
40.00%	78
45.00%	88
50.00%	98
55.00%	107
60.00%	118
65.00%	128
70.00%	139
75.00%	152
80.00%	166
85.00%	183
90.00%	206
95.00%	243

External validation

To further verify the accuracy of the nomogram prediction system mentioned above, data on HPV typing, age, status of surgical margins, and treatment outcomes of an additional 31 patients were collected. The nomogram prediction system described above was used to make predictions and conduct validation, with the results shown in Table 5. Among the additional 31 patients, only 3 were predicted incorrectly. The prediction accuracy of the external validation was: 28/31 = 90.3%.

DCA

The nomogram prediction scoring system, which was established based on the three indicators of age, HPV typing, and status of surgical margins, was further evaluated to examine the net benefit for patients based on the nomogram prediction system and to demonstrate that the net benefit of the nomogram prediction system was higher than that of predicting recurrence using any single indicator. The DCA is shown in Figure 4. The yellow color represents the combined prediction of recurrence using age, HPV typing, and status of surgical margins. The yellow curve is at the top, indicating that the combined prediction using these three indicators yields the highest net benefit for patients, which corresponds to the highest prediction accuracy.

Table 5: Accuracy of the nomogram prediction system for the 31 patients

Patient number	Age	HPV	Margins	Nomogram score	Predicting results	Actual results	Discrimination results
NO.1	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.2	≥45 years old	Other	The margin involves the external os	77	Cure	Cure	√
NO.3	< 45 years old	Other	The margin involves the internal os	83	Cure	Cure	√
NO.4	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.5	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Recurrence	×
NO.6	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.7	≥45 years old	Other	The margin involves the external os	77	Cure	Cure	√
NO.8	< 45 years old	HPV 16/18	The margin involves the internal os	144	Recurrence	Recurrence	√
NO.9	< 45 years old	Other	The margin involves the internal os	83	Cure	Cure	√
NO.10	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.11	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.12	≥45 years old	HPV 16/18	The margin involves the external os	138	Recurrence	Recurrence	√
NO.13	< 45 years old	HPV 16/18	The margin involves the internal os	144	Recurrence	Cure	×
NO.14	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.15	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.16	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√

NO.17	≥45 years old	Other	The margin involves the external os	77	Cure	Cure	√
NO.18	< 45 years old	Other	The margin involves the internal os	83	Cure	Cure	√
NO.19	< 45 years old	Other	The margin involves the external os	0	Cure	Cure	√
NO.20	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.21	< 45 years old	Other	The margin involves the external os	0	Cure	Recurrence	×
NO.22	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.23	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.24	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.25	< 45 years old	HPV 16/18	The margin involves the external os	61	Cure	Cure	√
NO.26	≥45 years old	HPV 16/18	The margin involves the external os	138	Recurrence	Recurrence	√
NO.27	≥45 years old	HPV 16/18	The margin involves the internal os	221	Recurrence	Recurrence	√
NO.28	≥45 years old	HPV 16/18	Positive inner and outer margins	238	Recurrence	Recurrence	√
NO.29	< 45 years old	Other	The margin involves the internal os	83	Cure	Cure	√
NO.30	≥45 years old	Other	The margin involves the external os	77	Cure	Cure	√
NO.31	< 45 years old	HPV 16/18	Positive inner and outer margins	161	Recurrence	Recurrence	√

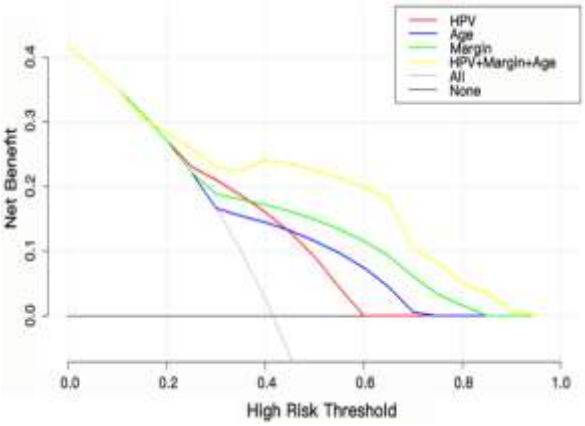

Figure 4: DCA

Additionally, the green curve, which is below the yellow curve, indicates that among the three factors, the status of surgical margins has the strongest predictive ability. Lastly, the red and blue curves are interwoven, indicating that the prediction accuracy of age and HPV typing is similar

Discussion

The primary objective of this article was to explore the predictive factors for recurrence in patients with cervical high-risk lesions after their first cervical conization and to construct a predictive scoring system for recurrence risk. Through retrospective analysis of clinical data from 120 patients, this article identified several factors associated with recurrence and successfully established a predictive model with high accuracy. The study results showed that patients aged ≥45 years had a significantly higher recurrence rate compared to those aged <45 years (P = 0.0), and age ≥45 years was identified as an independent risk factor for recurrence (OR = 4.5, 95% CI = 1.1-18.0). This finding is consistent with existing literature, indicating that as age increases, women's immune function may gradually decline, leading to a higher likelihood of cervical lesion recurrence. Particularly for postmenopausal women, hormonal changes and immune function decline may be potential reasons for increased recurrence risk. Therefore, age is a very important factor, and follow-up and treatment for this group should be given special attention. HPV infection, especially high-risk HPV types (such as HPV 16/18), is closely related to cervical precancerous lesions and recurrence. This article found that patients infected with HPV 16/18 had a significantly increased risk of recurrence (P = 0.0), and multivariate analysis also confirmed that HPV 16/18 infection is an independent predictor of recurrence (OR = 3.4, 95% CI = 1.4-8.3). This result is consistent with previous studies,[22,23] suggesting that persistent infection with high-risk HPV may lead to persistent abnormalities in cervical epithelial cells, thereby increasing the risk of recurrence. Immunological monitoring and antiviral treatment for such patients should be given special emphasis.

The impact of positive surgical margins and their location on recurrence is also a key finding of this article. Patients with margins at the internal or external os had a significantly increased risk of recurrence, especially those with positive margins at the internal os, whose risk of recurrence was five times higher than those with positive margins at the external os (OR = 5.5, 95% CI = 1.8-16.9). Moreover, when the margins involved both the internal and external os, the risk of recurrence further increased (OR = 7.3, 95% CI = 1.3-42.6). This phenomenon may be related to the extent of lesion spread and the completeness of lesion removal during surgery. Positive margins at the internal or external os may indicate that the lesion has not been completely removed, thereby increasing the likelihood of recurrence.[24] Therefore, after surgery, especially for patients with positive margins, follow-up should be strengthened, and further treatment options should be considered. However, although this article showed that patients who underwent reoperation had a higher recurrence rate, the results of multivariate analysis indicated that clinical management had no significant independent impact on recurrence (P = 0.6). This may be due to the combined effects of various factors, such as postoperative recovery, patient's immune status, rather than a single treatment method. Therefore, future studies may need to explore the effectiveness of different treatment strategies in specific patient groups and incorporate these factors into clinical decision-making.

Based on age, HPV typing, and status of surgical margins, a predictive model for recurrence risk was constructed and presented in the form of a

nomogram in this article. The predictive model is capable of providing risk scores for recurrence in different patients, aiding clinicians in making more precise treatment decisions. In the external validation section, the model was validated using data from an additional 31 patients, with results showing a prediction accuracy of 90.3%. This high accuracy indicates that the model has good external applicability across different patient populations. Through DCA, the clinical application value of the recurrence prediction model was further assessed. The DCA results showed that the combined prediction model (age, HPV typing, and surgical margins) had higher net benefit compared to single-factor prediction, meaning that using this model can maximize the accuracy and benefit of clinical decision-making. In particular, the combined prediction of HPV typing and surgical margins demonstrated stronger predictive ability. In summary, this article has constructed a recurrence prediction scoring system based on age, HPV typing, and surgical margins, which has high accuracy and clinical application value. In the future, with the accumulation of more clinical data and further optimization of the model, this prediction tool is expected to become an important auxiliary tool for guiding the management of patients with cervical lesions. However, further research is still needed to explore the specific mechanisms of action of these factors and to consider other potential influencing factors to further improve the precision of recurrence prediction.

Strengths and limitations

Research advantage is as follows. This study, through a retrospective analysis of clinical data from 120 patients, identified multiple factors associated with the recurrence of high-risk cervical lesions, offering substantial clinical reference value. By analyzing real-world data, it provides a more practical basis for clinical decision-making. A recurrence risk prediction scoring system was successfully developed, based on age, HPV genotype, and surgical margin status. The model demonstrated a 90.3% predictive accuracy during external validation, indicating strong predictive power and excellent external applicability. Multivariate analysis revealed not only the impact of individual factors but also integrated multiple clinical factors, such as age, HPV infection type, and surgical margins, providing a more comprehensive perspective and higher accuracy for recurrence prediction. Using DCA, it was confirmed that this prediction model offers a higher net benefit in predicting recurrence risk compared to individual clinical indicators, providing more reliable support for clinical decision-making and enhancing the accuracy of personalized treatment.

Research limitations are as follows. This study is a retrospective cohort study, which, although providing valuable clinical data, also carries a certain risk of bias, particularly with the potential for missing or incomplete data during the data collection process. Additionally, retrospective analysis cannot control for potential confounding factors, making it impossible to exclude the influence of certain external variables on the study results. Despite including 120 patients, the sample size is relatively small, particularly with only 31 patients' data used for external validation. The limited sample size may restrict the model's broad applicability and the reliability of the results. Therefore, further studies with a larger sample size are needed to validate the model's effectiveness in diverse populations. The data in this study were sourced from a single hospital, and the specific clinical practices, patient demographics, and resource allocation of that institution may have influenced the findings. Future research should consider multicenter, large-scale data to enhance the generalizability and representativeness of the results. Although key factors such as age, HPV type, and surgical margins were considered, cervical lesion recurrence may also be influenced by other factors, such as the patient's immune status, lifestyle, and genetic factors. Future studies should further explore these potential influences to enhance the accuracy of the predictive model.

The impact of research findings on policy and practice is as follows. The recurrence risk prediction scoring system proposed in this study holds significant clinical application value, aiding clinicians in more accurately assessing the risk of recurrence in patients with high-risk cervical lesions, thereby enabling the development of more personalized treatment and follow-up plans.

Specifically, by integrating key factors such as age, HPV type, and surgical margin status, this predictive model provides essential support for clinical decision-making, improving patient outcomes and quality of life. Furthermore, the study's findings contribute to the formulation of relevant clinical management strategies, particularly in the treatment and follow-up of specific populations (*e.g.*, older patients or those with high-risk HPV infections), offering a more scientifically grounded approach. As more clinical data are accumulated and the model undergoes further optimization, this predictive tool is expected to become a crucial adjunct in the management of cervical lesions. However, policymakers and clinicians should consider the limitations of this study when applying the model, conducting large-scale, multicenter validations, and incorporating additional influencing factors to ensure the model's broad applicability and accuracy.

Conclusion

Through retrospective analysis of clinical data from patients with cervical high-risk lesions after their first cervical conization, the main factors influencing recurrence were successfully identified, and a predictive scoring system for recurrence risk based on age, HPV typing, and status of surgical margins was constructed. The predictive model can effectively quantify the recurrence risk in different patients and provide important decision support for clinicians. The study results showed that age ≥45 years, HPV 16/18 infection, and positive surgical margins at the internal or external os are independent predictors of recurrence. The established nomogram provides a visual tool for clinicians to assess patients' recurrence risk. In addition, external validation and DCA further demonstrated the high accuracy and clinical value of the predictive model. Overall, the predictive model of this article can support the management of patients with cervical high-risk lesions after surgery, help clinicians make individualized treatment decisions, and thereby improve patient prognosis. However, further multicenter, large-sample studies and continuous model optimization remain the focus of future work to continuously improve the accuracy and practicality of recurrence risk prediction.

Conflicting of interests

The authors declare no competing interests.

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Authors contribution

Shuxia Wu and Xingye Ren were responsible for conception and design. Shuxia Wu was responsible for manuscript writing. Miaomiao Li and Xingye Ren were responsible for collection and assembly of data. Shuxia Wu, Miaomiao Li, and Xingye Ren were responsible for data analysis and interpretation. All authors were responsible for manuscript writing. All authors were responsible for the final approval of the manuscript

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