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Risk Stratification of Early-Stage Cervical Cancer with Intermediate-Risk Factors: Model Development and Validation Based on Machine Learning Algorithm

Ran Chu,[a] Yue Zhang,[a] Xu Qiao,[b] Lin Xie,[c] Wei Chen,[b] Ying Zhao,[a] Yintao Xu,[a] Zeng Yuan,[a] Xiaolin Liu,[a] Aijun Yin,[a] Zhiwen Wang,[b] Qing Zhang,[a,d] Xingsheng Yang,[a] Xuantao Su,[b] Beihua Kong,[a,d] Kun Song[a,d]

[a]Department of Obstetrics and Gynecology, Qilu Hospital, Cheeloo College of Medicine, Shandong University, Jinan, Shandong, People's Republic of China; [b]School of Control Science and Engineering, Shandong University, Jinan, Shandong, People's Republic of China; [c]Department of Obstetrics and Gynecology, Jining No.1 People's Hospital, Jining, Shandong, People's Republic of China; [d]Gynecology Oncology Key Laboratory, Qilu Hospital, Shandong University, Jinan, Shandong, People's Republic of China

Disclosures of potential conflicts of interest may be found at the end of this article.

Key Words. Cervical cancer • Intermediate-risk factor • Adjuvant therapy • Sedlis criteria • Prediction model • Machine learning algorithm

Abstract

Background. Adjuvant therapy for patients with cervical cancer (CC) with intermediate-risk factors remains controversial. The objectives of the present study are to assess the prognoses of patients with early-stage CC with pathological intermediate-risk factors and to provide a reference for adjuvant therapy choice.

Materials and Methods. This retrospective study included 481 patients with stage IB–IIA CC. Cox proportional hazards regression analysis, machine learning (ML) algorithms, Kaplan-Meier analysis, and the area under the receiver operating characteristic curve (AUC) were used to develop and validate prediction models for disease-free survival (DFS) and overall survival (OS).

Results. A total of 35 (7.3%) patients experienced recurrence, and 20 (4.2%) patients died. Two prediction models were built for DFS and OS using clinical information, including age, lymphovascular space invasion, stromal invasion, tumor size, and adjuvant treatment. Patients were divided into high-risk or low-risk groups according to the risk score cutoff value. The Kaplan-Meier analysis showed significant differences in DFS ($p = .001$) and OS ($p = .011$) between the two risk groups. In the traditional Sedlis criteria groups, there were no significant differences in DFS or OS ($p > .05$). In the ML-based validation, the best AUCs of DFS at 2 and 5 years were 0.69/0.69, and the best AUCs of OS at 2 and 5 years were 0.88/0.63.

Conclusion. Two prognostic assessment models were successfully established, and risk grouping stratified the prognostic risk of patients with CC with pathological intermediate-risk factors. Evaluation of long-term survival will be needed to corroborate these findings. ***The Oncologist*** 2021;26:e2217–e2226

Implications for Practice: The Sedlis criteria are intermediate-risk factors used to guide postoperative adjuvant treatment in patients with cervical cancer. However, for patients meeting the Sedlis criteria, the choice of adjuvant therapy remains controversial. This study developed two prognostic models based on pathological intermediate-risk factors. According to the risk score obtained by the prediction model, patients can be further divided into groups with high or low risk of recurrence and death. The prognostic models developed in this study can be used in clinical practice to stratify prognostic risk and provide more individualized adjuvant therapy choices to patients with early-stage cervical cancer.

Correspondence: Kun Song, M.D., Department of Obstetrics and Gynecology, Qilu Hospital of Shandong University, 107 Wenhua Xi Road, Jinan, Shandong, People's Republic of China. Telephone: 08-053182169545; e-mail: songkun2001226@sdu.edu.cn Received June 25, 2020; accepted for publication July 12, 2021; published Online First on September 16, 2021. http://dx.doi.org/10.1002/onco.13956

Introduction

Every year, more than 500,000 women are diagnosed with cervical cancer (CC), and more than 300,000 deaths occur due to this disease worldwide [1]. Although cervical screening strategies have decreased the incidence of CC, data from global population-based CC registries have revealed that 5-year survival has improved only slightly in recent decades [2]. Furthermore, nearly 90% of deaths from CC occur in developing and low-resource countries [3]. The prognosis of patients with CC is closely related to the clinical staging system determined by the International Federation of Gynecology and Obstetrics (FIGO). Radical hysterectomy with pelvic lymphadenectomy is the preferred surgical plan for patients with early CC [4]. Surgical risk factors and lymph node status were first included in the FIGO staging system in 2018 [5]. In addition to lymph node status, other pathological risk indicators widely recognized to affect survival and recurrence in CC include parietal infiltration and marginal positivity [6–9]. Furthermore, the Gynecologic Oncology Group (GOG) defined lymphovascular space invasion (LVSI), stromal invasion (SI), and tumor size as "Sedlis criteria," which are intermediate-risk factors used to guide adjuvant treatment decisions [10].

For patients with early-stage CC who meet the Sedlis criteria, controversies remain regarding adjuvant therapy after surgical treatment. The European Society for Medical Oncology clinical practice guidelines for CC recommend that patients with intermediate-risk do not need further adjuvant therapy (evidence level II, B) [3]. The FIGO CC report recommends that postoperative radiotherapy is required, but chemotherapy is not recommended, if a patient exhibits any two of the following risk factors: tumor size more than 4 cm, LVSI, and deep SI [5]. The National Comprehensive Cancer Network clinical practice guidelines for CC recommend pelvic external beam radiation therapy (category 1) with or without concurrent platinum-containing chemotherapy (category 2B for chemotherapy) for lymph node–negative, postsurgery patients who were diagnosed at stage IA2, IB1, or IIA1 and have large primary tumors, deep SI, and/or LVSI [11].

Therefore, evaluation of intermediate-risk factors and adjuvant therapy remains controversial, and potential intermediate-risk factors for both recurrence and survival may include factors beyond the Sedlis criteria. Patients with early-stage CC typically have a favorable prognosis, and radiotherapy is often associated with considerable adverse effects during adjuvant therapy [12]. Thus, participating clinicians must identify the suitable management method after surgery to avoid overtreatment. At present, there are no published survival prediction models for predicting overall survival (OS) or disease-free survival (DFS) of patients with early-stage CC by pathological intermediate-risk factors.

The objective of our study is to establish prognostic evaluation models and stratify the prognostic risk in patients with CC with intermediate-risk factors. Our results provide a more individualized reference for planning postoperative adjuvant treatment in clinical practice.

Materials and Methods

Patients

After the study obtained approval from the Ethical Committee of Qilu Hospital of Shandong University (protocol number 2018 066) and received a waiver for informed consent, 481 patients with CC who had received treatment at Qilu Hospital of Shandong University between January 2005 and December 2016 were included in our study. All patients met the following inclusion criteria: (a) stage IB–IIA CC according to the 2009 FIGO staging system [13]; (b) primary treatment by radical or modified radical hysterectomy and pelvic lymphadenectomy. The exclusion criteria were (a) lymph node metastasis, parametrial involvement, or positive resection margin after surgery; (b) the presence of other primary malignant tumors; (c) insufficient medical records.

Predictors and Endpoints

The following clinical characteristics were included: age, FIGO stage (2009), histology, histological grade, LVSI, SI, tumor size, adjuvant therapy after surgery, and survival and recurrence information. Recurrence and death were defined as the primary outcomes of this study. DFS and OS were described as the time interval from surgery to the first evidence of any recurrence and death or last follow-up. The tumor size was measured by clinical palpation.

Model Development

The workflow of this study is presented in Figure 1. Each characteristic was estimated using univariable Cox survival analysis for both DFS and OS, and results were described as hazard ratios (HRs), with associated 95% confidence intervals (CIs), and p values. After selection of risk factors, the age, pathological risk factors as defined in the Sedlis criteria (LVSI, SI, and tumor size), and adjuvant treatment methods were entered into a multivariable Cox proportional hazards regression analysis to construct intermediate-risk prediction models. The time-dependent receiver operating characteristic (ROC) curves and the area under the ROC curve (AUC) were used to evaluate the discrimination ability of the model. Nomogram lists were developed to predict the risk of 2- and 5-year DFS, as well as 2- and 5-year OS. We then calculated the risk score of each patient according to the nomogram lists, selecting the median risk score as the cutoff value. Patients were divided into low-risk and high-risk groups according to risk score. A heatmap was generated based on the distribution of risk factors in the two groups. The Kaplan-Meier method with the log-rank test was used to compare the abilities of the traditional Sedlis criteria and the new risk groups from the developed model to distinguish prognoses.

Model Validation

Currently, machine learning (ML) is often used in the development and validation of prediction models in clinical research [14]. We divided patients into four groups according to whether there was recurrence or death within 2 and 5 years of the primary surgery. ML algorithms,

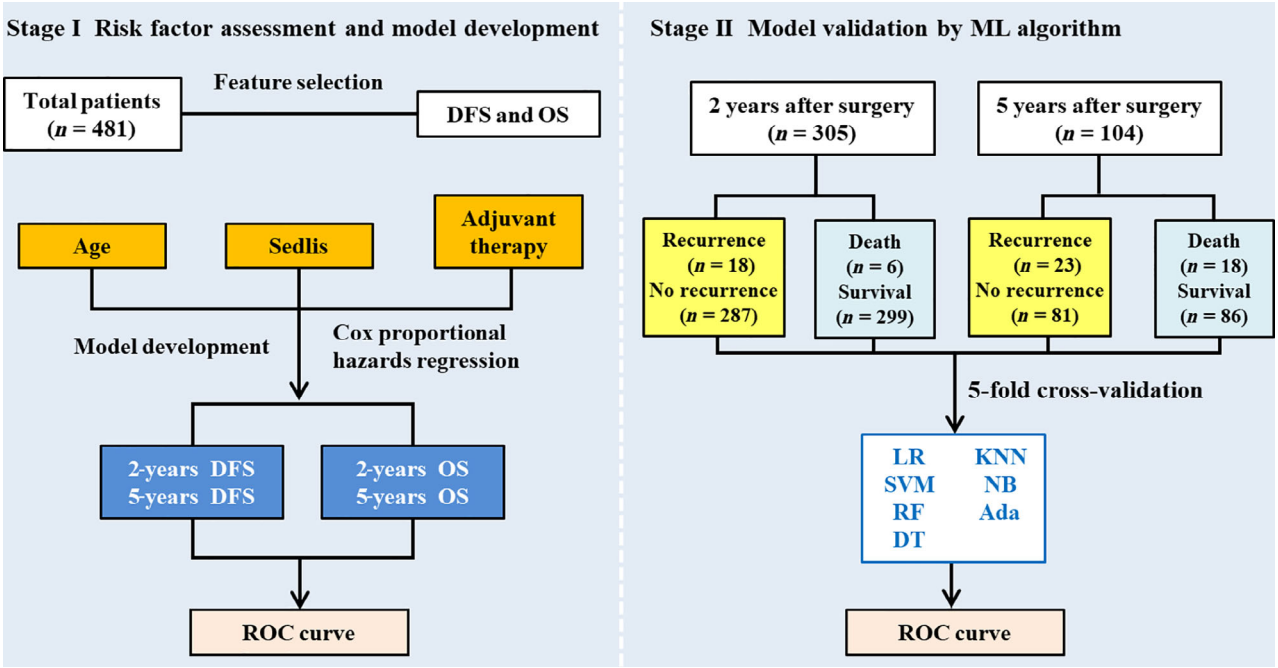

Figure 1. The workflow of this study.
Abbreviations: Ada, AdaBoost; DFS, disease-free survival; DT, decision tree; KNN, k-nearest neighbor; LR, logistic regression; ML, machine learning; NB, naïve Bayes; OS, overall survival; RF, random forest; ROC, receiver operating characteristic; SVM, support vector machine.

including logistic regression (LR), support vector machine (SVM), random forest (RF), decision tree, k-nearest neighbor, naïve Bayes, and AdaBoost, were used for model validation. Fivefold cross-validation was applied for each algorithm. All patients were randomly partitioned into five equal-sized subsamples. Four subsamples were used in training data, and the final subsample was selected as the validation data for testing. AUCs were calculated over multiple rounds of cross-validation to assess the models.

Statistical Analysis

The descriptive statistical analysis, univariate and multivariate Cox proportional hazard regression analysis, nomogram lists, ROC analysis, and log-rank test were conducted with R (version 3.6.1). The ML algorithms were conducted in Python (version 3.6.4) using the machine learning library scikit-learn (version 0.19.1).

Results

Patient Characteristics

Patient characteristics are reported in Table 1. In 481 patients with early-stage CC, 344 (71.5%) women were diagnosed at stage IB1, 94 (19.5%) at stage IB2, 25 (5.2%) at stage IIA1, and 18 (3.7%) at stage IIA2. Most patients underwent laparotomy with radical hysterectomy ($n = 385$, 80%), and 379 (80.9%) patients received adjuvant therapy after surgery. After a median follow-up period of 31 months (range, 9–145 months), 35 (7.3%) patients experienced recurrences, and 20 (4.2%) died. The 2-year DFS and OS were 94.1% and 98.0%, respectively, and the 5-year DFS and OS were 77.9% and 82.7%, respectively.

Predictor Assessment of DFS and OS

As shown in Table 2, there was a significant association between patients older than 40 years and postoperative recurrence (HR 2.60, 95% CI 1.02–6.78, $p = .046$), whereas the association between this age group and death was weaker (HR 3.95, 95% CI 0.92–17.02, $p = .065$). Furthermore, the FIGO stage (2009), operation method, histology, histological grade, LVSI, SI, tumor size, and adjuvant therapy were not significantly associated with either DFS or OS.

Model Development of DFS and OS

Multivariable Cox proportional hazards regression used age, LVSI, SI, tumor size, and adjuvant treatment method to develop prediction models for DFS and OS. The two models are shown as nomogram lists in Figure 2. The risk score for DFS = 100 × (age > 40 years) + 66.8 × (LVSI [+]) + 3.5 × middle 1/3 invasion +62.8 × deep 1/3 invasion +14.4 × (tumor size ≥2 cm) + 79.5 × (tumor size ≥4 cm) + 98.4 × (tumor size ≥5 cm) + 66.8 × no adjuvant treatment +12.2 × chemotherapy +19.7 × chemotherapy and radiotherapy. The risk score for OS = 100 × (age > 40 years) + 51.9 × (LVSI [+]) + 13.3 × superficial 1/3 invasion +54.8 × deep 1/3 invasion +37.1 × (tumor size ≥2 cm) + 99.3 × (tumor size ≥4 cm) + 77.6 × (tumor size ≥5 cm) + 80.5 × no adjuvant treatment +10.4 × chemotherapy +60.3 × chemotherapy and radiotherapy.

ROC curves for both models are shown in supplemental online Figure 1. The recurrence model yielded an AUC of

Table 1. Characteristics of patients

Characteristic	Total ($n = 481$)	Recurrence ($n = 35$, 7.3%)	Death ($n = 20$, 4.2%)
Age, years			
≤40	137 (28.5)	5 (14.3)	2 (10.0)
>40	344 (71.5)	30 (85.7)	18 (90.0)
FIGO stage (2009)			
IB1	344 (71.5)	24 (68.6)	15 (75.0)
IB2	94 (19.5)	9 (25.7)	4 (20.0)
IIA1	25 (5.2)	2 (5.7)	1 (5.0)
IIA2	18 (3.7)	0 (0.0)	0 (0.0)
Operation method			
Laparotomy	385 (80.0)	30 (85.7)	18 (90.0)
Laparoscopy	96 (20.0)	5 (14.3)	2 (10.0)
Histology			
Squamous	390 (81.1)	9 (25.7)	5 (25.0)
Nonsquamous	91 (18.9)	26 (74.3)	15 (75.0)
Histological grade			
I (well differentiated)	41 (8.5)	2 (5.7)	13 (65.0)
II (moderately differentiated)	152 (31.6)	9 (25.7)	5 (25.0)
III (poorly differentiated)	288 (59.9)	24 (68.6)	2 (10.0)
LVSI			
No	376 (778.2)	27 (77.1)	16 (80.0)
Yes	105 (21.8)	8 (22.9)	4 (20.0)
Stromal invasion			
Superficial 1/3	134 (27.9)	7 (20.0)	4 (20.0)
Middle 1/3	185 (38.5)	9 (25.7)	4 (20.0)
Deep 1/3	162 (33.7)	19 (54.3)	12 (60.0)
Tumor size, cm			
<2	102 (21.4)	5 (14.3)	2 (10.0)
≥2	280 (58.2)	17 (48.6)	10 (50.0)
≥4	58 (12.1)	7 (20.0)	5 (25.0)
≥5	40 (8.3)	6 (17.1)	3 (15.0)
Adjuvant therapy			
None	92 (19.1)	8 (22.9)	5 (25.0)
Chemotherapy	222 (46.2)	14 (40.0)	6 (30.0)
Radiotherapy	20 (4.2)	2 (5.7)	1 (5.0)
Chemotherapy and radiotherapy	147 (30.6)	11 (31.4)	8 (40.0)

Values are presented as *n* (%).
Abbreviations: FIGO, International Federation of Gynecology and Obstetrics; LVSI, lymphovascular space invasion.

0.74 in 2-year DFS and 0.66 in 5-year DFS (supplemental online Fig. 1A). The death model yielded an AUC of 0.87 in 2-year OS and 0.69 in 5-year OS (supplemental online Fig. 1B). The time-dependent ROC curve is shown in supplemental online Figure 1C. To determine the effect of risk score on clinical outcome, we divided the cohort over the median risk score. In the recurrence model, patients with a risk score higher than 167 points were placed in the high risk of recurrence group (supplemental online Fig. 2A). In the death model, patients with a risk score higher than 194 points were placed in the high risk of death group (supplemental online Fig. 2B). The survival and recurrence time of each patient is shown in supplemental online Figure 2C, 2D. We compared the distribution of prognostic factors in the two groups by heatmap (supplemental online Fig. 2E, 2F), in which the red color indicates higher significance. Patients in the high-risk groups were older, had larger tumors, and had more diagnoses of positive LVSI and deep of cervical invasion.

Comparison of the Traditional Sedlis Criteria Groups and New Risk Groups

Patient distribution according to the traditional Sedlis criteria groups and the new risk groups defined in this study

Table 2. Univariable Cox proportional hazards regression analysis for DFS and OS

	DFS		OS	
Characteristic	**HR (95% CI)**	***p* value**	**HR (95% CI)**	***p* value**
Age, years		.046		.065
≤40	Reference		Reference	—
>40	2.63 (1.02–6.78)		3.95 (0.92–17.02)	
FIGO stage (2009)		.989		.933
IB1	Reference	—	Reference	—
IB2	1.06 (0.49–2.28)	.891	0.70 (0.23–2.10)	.519
IIA1	1.29 (0.30–5.44)	.733	1.06 (0.14–8.02)	.956
IIA2	—	—	—	—
Operation method		.350		.374
Laparotomy	Reference		Reference	
Laparoscopy	1.61 (0.60–4.32)		2.02 (0.43–9.45)	
Histology		.378		.640
Squamous	Reference		Reference	
Nonsquamous	0.71 (0.33–1.52)		0.79 (0.29–2.16)	
Histological grade		.561		.648
I (well differentiated)	Reference	—	Reference	—
II (moderately differentiated)	1.47 (0.35–6.23)	.600	0.73 (0.16–3.22)	.672
III (poorly differentiated)	0.99 (0.21–4.60)	.992	0.49 (0.10–2.54)	.398
LVSI		.385		.551
No	Reference		Reference	
Yes	1.42 (0.64–3.14)		1.40 (0.47–4.20)	
Stromal invasion		.130		.202
Superficial 1/3	Reference	—	Reference	—
Middle 1/3	1.04 (0.39–2.78)	.946	0.82 (0.21–3.30)	.784
Deep 1/3	2.02 (0.85–4.82)	.111	2.04 (0.66–6.33)	.218
Tumor size, cm		.126		.239
<2	Reference	—	Reference	—
≥2	1.24 (0.46–3.35)	.678	1.82 (0.40–8.30)	.441
≥4	2.29 (0.73–7.23)	.157	3.88 (0.75–20.02)	.105
≥5	3.09 (0.94–10.13)	.063	4.00 (0.67–23.96)	.129
Adjuvant therapy		.822		.363
None	Reference	—	Reference	—
Chemotherapy	0.71 (0.30–1.69)	.435	0.49 (0.15–1.60)	.237
Radiotherapy	0.72 (0.15–3.43)	.682	0.52 (0.06–4.50)	.555
Chemotherapy and radiotherapy	0.97 (0.39–2.41)	.942	1.21 (0.40–3.70)	.740

Abbreviations: CI, confidence interval; DFS, disease-free survival; FIGO, International Federation of Gynecology and Obstetrics; HR, hazard ratio; LVSI, lymphovascular space invasion; OS, overall survival.

are shown in Table 3. The Kaplan-Meier analysis showed that the Sedlis criteria could not distinguish DFS or OS in patients with CC ($p > .05$; Fig. 3A–3D) and that high-risk groups for both recurrence and death were significantly associated with poor DFS ($p = .001$; Fig. 3E) and OS ($p = .011$; Fig. 3F).

Model Training and Validation Based on ML Algorithms

For further validation, ML algorithms were applied to verify the discrimination ability of the two models. Figure 4 shows the results from the fivefold cross-validation. The AUC of the 2-year DFS prediction model ranged from 0.61 to 0.69, with the highest AUC produced by the SVM algorithm (Fig. 4A). In the 5-year DFS model, the AUC ranged from 0.64 to 0.69, and the LR calculation yielded the highest AUC (Fig. 4B). The best AUC was obtained for the 2-year OS prediction model, which ranged from 0.84 to 0.88 (Fig. 4C), and the AUC of the 5-year OS prediction model ranged from 0.60 to 0.63 (Fig. 4D). Overall, the LR and SVM algorithms had good discrimination compared with the other five algorithms in the fivefold cross-validation process.

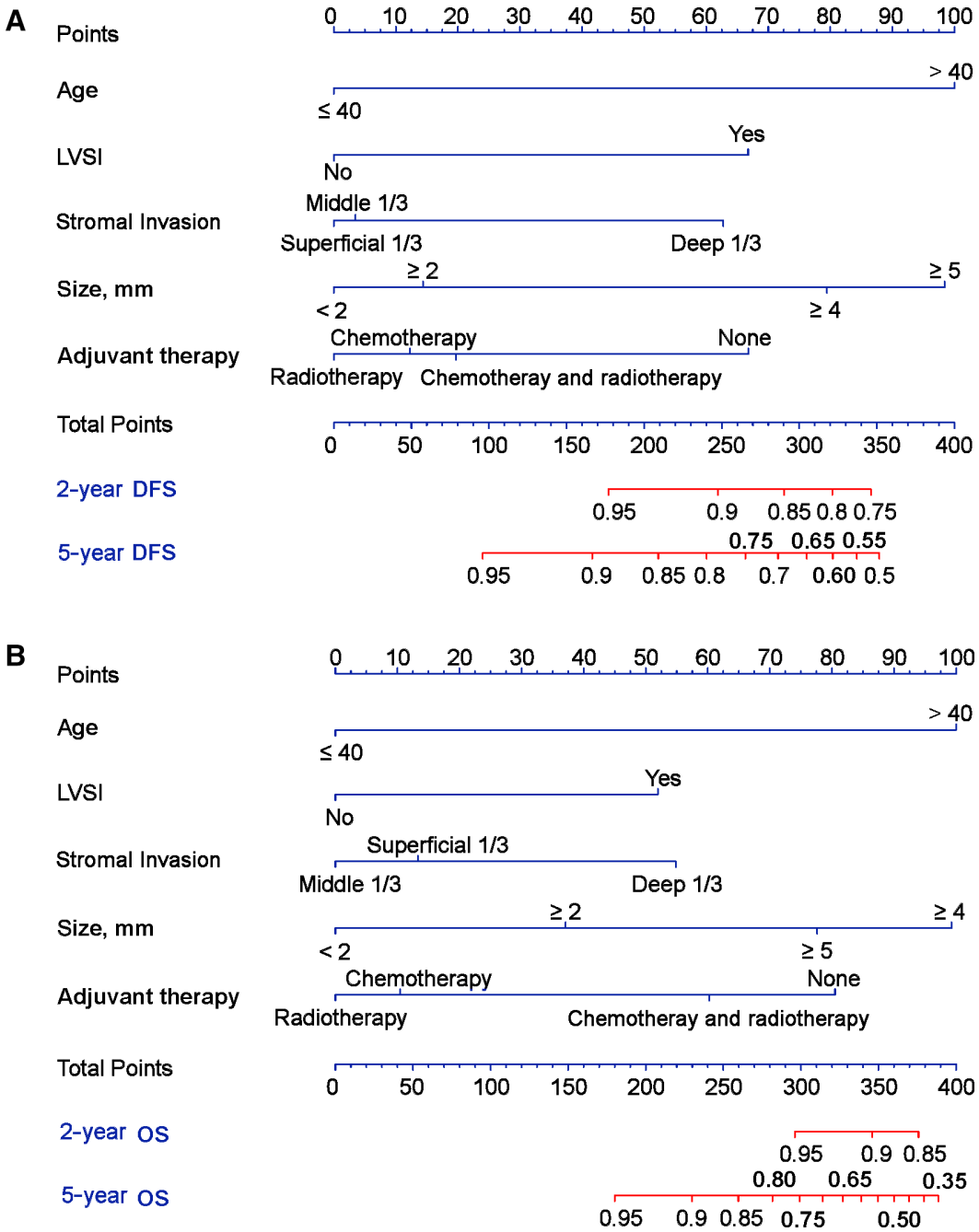

Figure 2. Nomogram lists of risk prediction models for DFS **(A)** and OS **(B)**.
Abbreviations: DFS, disease-free survival; LVSI, lymphovascular space invasion; OS, overall survival.

Discussion

The present paper describes the development of prediction models for DFS and OS in patients with early-stage CC based on pathological intermediate-risk factors and postoperative adjuvant therapy. The prediction models were constructed by age, LVSI, depth of SI, tumor size, and postoperative adjuvant therapy. We found significant differences in DFS and OS between patients in the high-risk and low-risk groups and showed that risk grouping can be used to stratify the prognostic risk of early-stage CC in patients with intermediate-risk factors. Finally, we used ML algorithms to validate the models. Our results suggest that the favorable prognostic risk assessment model could be used in clinical practice as a potential postoperative evaluation tool for patients with early-stage CC.

The Sedlis criteria, which were proposed by the GOG through a prospective study, are currently widely used and include three factors (LVSI, deep of SI, and tumor size) [10]. A retrospective study of CC showed that although 50% of recurrences in the study occurred in patients who did not meet the criteria, all recurrences occurred in patients with two or more pathological intermediate-risk factors [15]. These results show that the risk factors in the Sedlis criteria need to be further optimized to accurately evaluate the prognoses of patients with early-stage CC.

Table 3. The information of patients in traditional Sedlis criteria groups and new risk groups

Groups according to Sedlis criteria	Total ($n = 481$)	Recurrence ($n = 35$, 7.3%)	Death ($n = 20$, 4.2%)
Sedlis criteria (detailed)			
None	337 (70.1)	22 (62.9)	13 (65.0)
LVSI + Deep 1/3	32 (6.7)	3 (8.6)	1 (5.0)
LVSI + Middle 1/3 + Tumor size ≥2 cm	39 (8.1)	3 (8.6)	2 (10.0)
LVSI + Superficial 1/3 + Tumor size ≥5 cm	0 (0.0)	0 (0.0)	0 (0.0)
Middle or deep 1/3 + Tumor size ≥4 cm	73 (15.2)	7 (20.0)	4 (20.0)
Sedlis criteria			
No	337 (70.1)	22 (62.9)	13 (65.0)
Yes	144 (29.9)	13 (37.1)	7 (35.0)
Risk group of recurrence			
Low-risk group	224 (46.6)	7 (20.0)	4 (20.0)
High-risk group	257 (53.4)	28 (80.0)	16 (80.0)
Risk group of death			
Low-risk group	248 (51.6)	10 (28.6)	4 (20.0)
High-risk group	233 (48.4)	25 (71.4)	16 (80.0)

Values are presented as *n* (%).
Abbreviation: LVSI, lymphovascular space invasion.

In the U.S., the median age of patients with CC at diagnosis is 47 years, and almost 50% of patients are diagnosed at ages below 35 years [16]. In addition, in developing nations such as South Africa, more than 25% of patients with CC are diagnosed between the ages of 40 and 49 [17]. These data suggest that a significant proportion of patients with CC are young adults. Moreover, the univariable survival analysis performed in the present study shows that women older than 40 years were more likely to be diagnosed with a recurrence. Therefore, we included age as one of the risk factors and constructed the multivariable Cox proportional hazards regression models with other intermediate-risk factors. In a population-based study, after a 7-year follow-up, the advanced-stage disease was more likely to be diagnosed among women aged 50 years and older (2.2–2.5 times the diagnosis rate of patients aged 21–34 years) [18]. Thus, for older patients with intermediate-risk factors, the adjuvant treatment plan after the primary surgery needs to be carefully discussed.

The intent of primary surgery for early-stage CC is therapeutic and diagnostic, and surgical staging may provide pathological evidence for subsequent adjuvant treatment [19]. As lymph node status and surgical risk factors have been included in the FIGO staging system for CC [5], more pathological and surgical factors should be considered for the patient's prognosis, such as histology, grade, LVSI, SI, tumor size, and operation method. In our study, all patients underwent radical or modified radical hysterectomy and pelvic lymphadenectomy to complete surgical staging. However, the univariable Cox proportional hazards regression analysis indicted that none of the above risk factors were significantly associated with DFS or OS. On the one hand, this result reflects the low sensitivity of these intermediate-risk factors (LVSI, SI, and tumor size), which is in line with the previous study [15]. On the other hand, selecting the adequate adjuvant therapy may improve the prognosis of patients [20]. The multivariable Cox model assesses the relationship between the different combinations of intermediate-risk factors and prognoses comprehensively, and adjuvant therapy was included in the development process of the model. Several studies have shown that radiotherapy decreases the incidence of local recurrence but has little effect on OS [21–23]. Our results show that radiotherapy can reduce the incidence of both recurrence and death in patients without high-risk pathological factors. Moreover, recent research has suggested that concurrent chemoradiotherapy can confer further benefits to patients [24–27]. It remains to be determined whether concurrent chemoradiotherapy is necessary for patients with intermediate-risk factors.

Tumor size in our study was obtained by preoperative clinical palpation, which is consistent with the Sedlis criteria, but measuring errors are unavoidable with this method. In a study by Ryu et al., tumor size was measured by abdominopelvic computed tomography (CT) or magnetic resonance imaging (MRI), which seem to be more accurate methods for identifying tumor size than clinical palpation. In high-income countries, MRI and CT have been increasingly used in the clinical staging of CC [28]. Furthermore, in the 2018 FIGO cancer report, imaging findings could be used for clinical stage assignment, which reflects the importance of the imaging evaluation [5].

The Sedlis criteria are used in clinical practice for patients with early-stage CC without pathological high-risk factors. Therefore, patients with lymph node metastasis, parametrial involvement, or positive resection margin were not included in this study. The strength of our study is to develop two prognostic evaluation models for

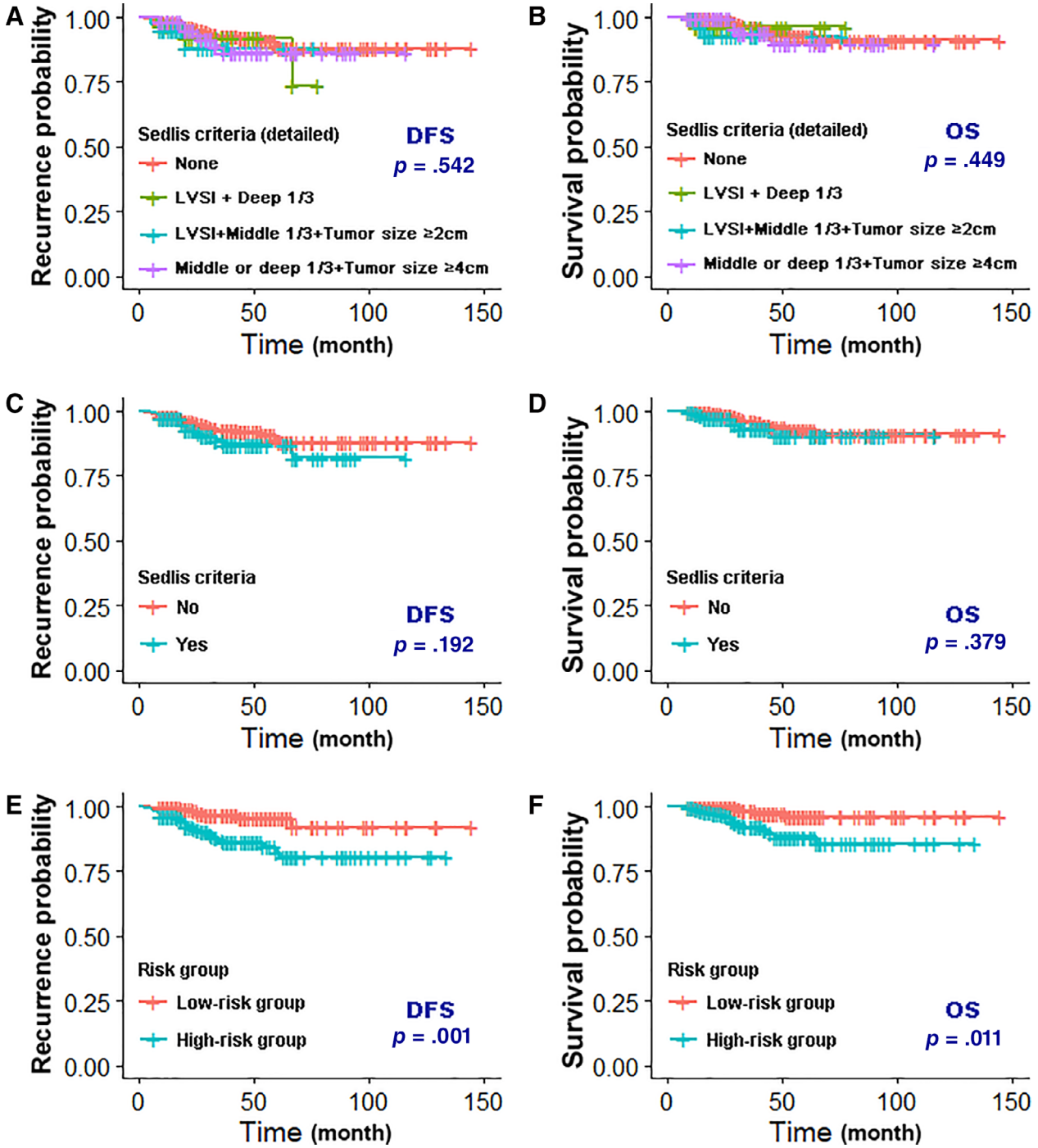

Figure 3. Kaplan-Meier analysis of the Sedlis criteria (detailed) with DFS **(A)** and OS **(B)**; Sedlis criteria with DFS **(C)** and OS **(D)**; and risk group with DFS **(E)** and OS **(F)**.
Abbreviations: DFS, disease-free survival; LVSI, lymphovascular space invasion; OS, overall survival.

patients with early-stage CC through a unique combination of intermediate-risk factors and an adjuvant therapy plan. Basing on the weighted risk factors in nomogram lists, these models can provide individualized predictions for each patient. Prognostic risk groups calculated by these models perform better than the traditional Sedlis criteria. The limitations of the present study include its retrospective nature and small sample size. Histology types (cervical squamous cell carcinoma and adenocarcinoma) were not separately modeled for prognosis in our study. Because the patients with CC in our study were classified as stage IB–IIA, according to the 2009 FIGO classification system, the postoperative adjuvant treatment rate was higher than in other studies. Moreover, we did not set up an independent validation cohort to validate the models. Instead, we chose ML algorithms by fivefold

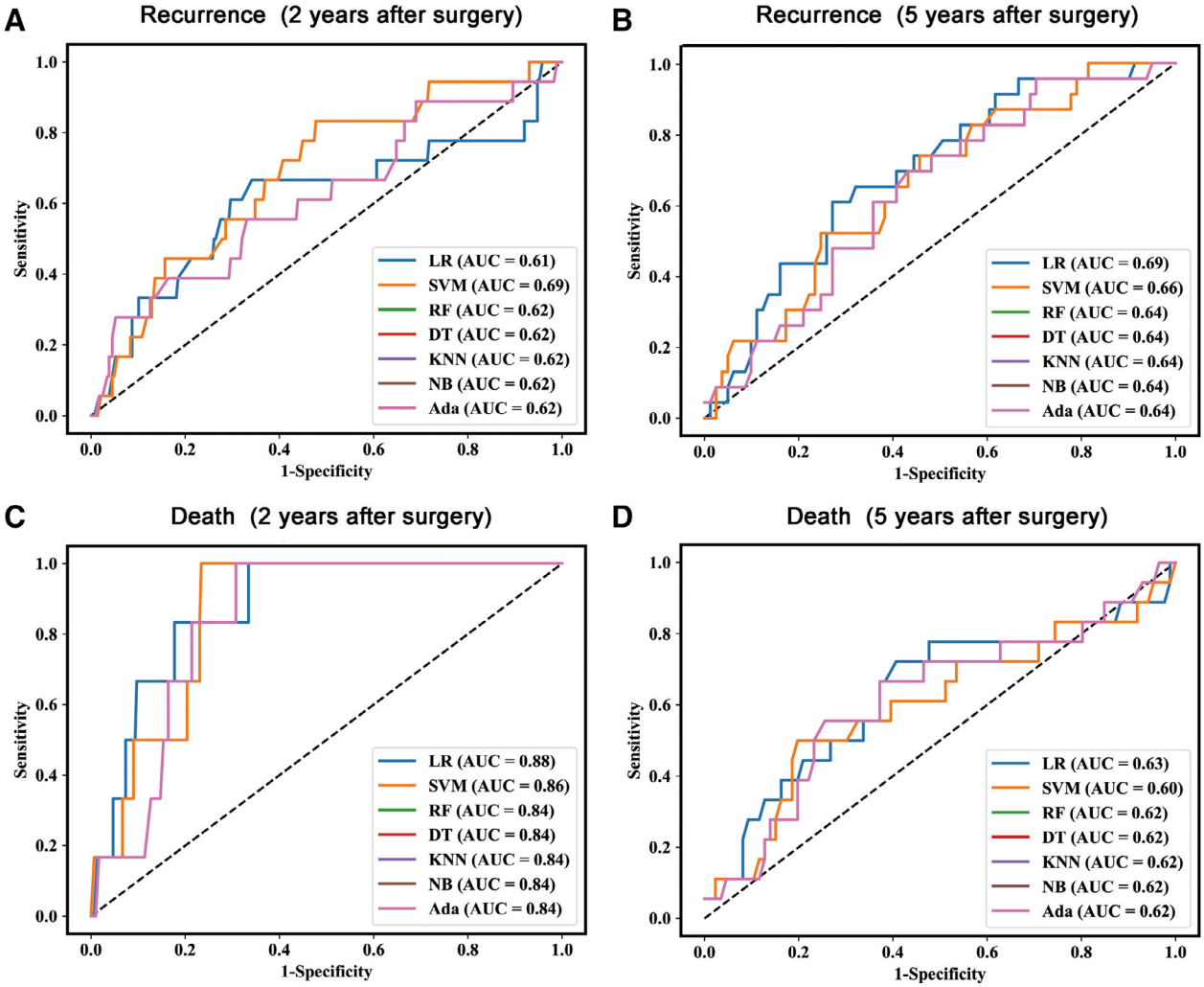

Figure 4. ROC curves of the ML-based validation of patient recurrence occurred within 2 years after surgery **(A)** and 5 years after surgery **(B)**; and patient death occurred within 2 years after surgery **(C)** and 5 years after surgery **(D)**.
Abbreviations: Ada, AdaBoost, AUC, area under the receiver operating characteristic curve; DT, decision tree; KNN, k-nearest neighbor; LR, logistic regression; NB, naïve Bayes; RF, random forest; SVM, support vector machine.

cross-validation to verify the predictive abilities of the models. Prospective validation will compensate for the above research limitations.

Conclusion

We developed two intermediate-risk factor models that can predict DFS and OS in patients with early-stage CC after initial surgical treatment. Risk grouping completed the prognostic risk stratification of patients. These models may provide more individualized predictions and provide a reference for adjuvant therapy choice. Prospective validation in future studies will be needed to improve the predictive abilities of the above models.

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Author Contributions

Conception/design: Ran Chu, Yue Zhang, Xu Qiao, Lin Xie, Wei Chen, Beihua Kong, Kun Song
Provision of study materials or patients: Beihua Kong, Kun Song
Collection and/or assembly of data: Yue Zhang, Lin Xie, Ying Zhao, Yintao Xu, Zeng Yuan, Xiaolin Liu, Aijun Yin, Zhiwen Wang, Qing Zhang, Xingsheng Yang, Xuantao Su
Data analysis and interpretation: Ran Chu, Lin Xie
Manuscript writing: Ran Chu, Yue Zhang
Final approval of manuscript: Ran Chu, Yue Zhang, Xu Qiao, Lin Xie, Wei Chen, Ying Zhao, Yintao Xu, Zeng Yuan, Xiaolin Liu, Aijun Yin, Zhiwen Wang, Qing Zhang, Xingsheng Yang, Xuantao Su, Beihua Kong, Kun Song

Disclosures

The authors indicated no financial relationships.

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