Available Online: 12 May 2025 DOI: 10.54254/3049-5458/2025.22897

Constructing and validating prognostic models for papillary renal cell carcinoma after different surgical procedures based on the SEER database

Qingdian Tang[1], Yaping Wan[1]*

[1]School of Public Health, University of South China, Hengyang, China

*Corresponding Author. Email: ypwan@usc.edu.cn

Abstract. Objective: To utilize clinical data of patients diagnosed with Papillary Renal Cell Carcinoma (PRCC) from the Surveillance, Epidemiology, and End Results (SEER) database (2010–2015) to construct and validate a prognostic model using a retrospective study design. Methods: Clinical and pathological data of 1,788 PRCC patients were extracted from the SEER database based on defined inclusion and exclusion criteria. The cohort was randomly divided into a training set (n = 1,252) and a validation set (n = 536) in a 7:3 ratio. Univariate and multivariate Cox regression analyses were conducted to identify clinical factors influencing prognosis. Based on these factors, a nomogram was developed to predict 1-year, 3-year, and 5-year Cancer-Specific Survival (CSS) rates. The model's discriminatory power and predictive performance were evaluated using the Concordance index (C-index), calibration curves, Area Under the Curve (AUC), and Receiver Operating Characteristic (ROC) analysis. Results: Univariate and multivariate Cox regression analyses identified age, gender, surgical method, pathological grade, and TNM stage as independent prognostic factors. These variables were incorporated into a Cox proportional hazards regression model to calculate risk scores and construct the nomogram. In the training set, the AUCs for 1-year, 3-year, and 5-year CSS predictions were 0.7978, 0.7813, and 0.7542, respectively. In the validation set, the AUCs were 0.6793, 0.7114, and 0.7174, respectively. Calibration curves demonstrated good agreement between predicted and observed survival outcomes, indicating adequate predictive accuracy. Conclusion: The prognostic nomogram model for patients with papillary renal cell carcinoma developed based on SEER database data provides reliable prognostic predictions and may support clinical assessment and decision-making.

Keywords: papillary renal cell carcinoma, prognostic analysis, nomogram prediction model

1. Introduction

Renal Cell Carcinoma (RCC) is a common malignant tumor originating from the renal parenchyma or renal cortex, with a rising incidence globally [1]. Papillary Renal Cell Carcinoma (pRCC) is the second most common subtype of RCC, accounting for approximately 15%–20% of all RCC cases [2]. Due to its relatively rare pathology, current research on the clinicopathological characteristics and survival prognosis of pRCC patients remains limited both domestically and internationally. Most domestic studies rely on small samples from single centers. The Surveillance, Epidemiology, and End Results (SEER) program of the U.S. National Cancer Institute collects incidence, mortality, and morbidity data from approximately 35% of the U.S. population across multiple centers [3]. This study extracted a large dataset of clinicopathological data on patients with pRCC from the SEER database, identified variables associated with Cancer-Specific Survival (CSS), and developed a nomogram to predict postoperative CSS in patients with pRCC. The goal is to provide clinicians with a more effective clinical assessment tool and to improve the diagnosis and treatment of pRCC.

2. Materials and methods

2.1. General information

Clinical data of patients diagnosed with pRCC were obtained from the SEER database using SEER*Stat version 8.4.0. Inclusion

criteria: 1) Pathologically confirmed diagnosis of papillary renal cell carcinoma; 2) Diagnosed between 2010 and 2015. Exclusion criteria: 1) Age over 85 years; 2) Tumor diameter greater than 500 mm; 3) Incomplete clinicopathological features or follow-up data.

2.2. Analyzed variables

Variables included in the study were: age at diagnosis, sex, race, laterality of the tumor, surgical method (including no surgery, cryoablation, nephroureterectomy involving unilateral nephrectomy, partial nephrectomy, and radical nephrectomy), histological grade, tumor size, and TNM staging based on the 7th edition of the American Joint Committee on Cancer (AJCC).

2.3. Statistical analysis

The dataset was randomly split into a training cohort and a validation cohort in a 7:3 ratio using the "caret" package in R version 4.2.2. Univariate and multivariate Cox regression analyses were conducted on the training cohort using the "survival" package to identify variables affecting survival time and outcomes. Significant prognostic factors were incorporated into a Cox proportional hazards model, and a nomogram was constructed using the "rms" package. Time-dependent Receiver Operating Characteristic (ROC) curves were generated using the "timeROC" package. The discriminative ability and accuracy of the prognostic prediction model were evaluated by the area under the ROC curve and calibration plots.

3. Results

3.1. Clinicopathological characteristics of patients

A total of 1,788 patients with pRCC were included and randomly assigned into a training cohort (n = 1,252) and a validation cohort (n = 536) in a 7:3 ratio. Among them: Patients over 60 years old accounted for a relatively high proportion (73.7%); Male patients comprised the majority (75.8%); Most patients underwent surgery (97.9%), primarily partial nephrectomy (48.9%) and radical nephrectomy (38.0%). There were no significant statistical differences in baseline characteristics between the training and validation cohorts ($P \geq 0.05$; see Table 1), indicating that the training cohort could be reliably used to construct the model, with the validation cohort used for verification.

Table 1. Comparison of clinicopathological characteristics between training and validation cohorts (n, %)

Variable	Training Cohort (N=1252)	Validation Cohort (N=536)	Total (N=1788)	P-value
Age				0.599
≤60	335 (26.8)	137 (25.6)	472 (26.3)	
>60	917 (73.2)	399 (74.4)	1316 (73.7)	
Sex				0.924
Male	948 (75.7)	407 (75.9)	1355 (75.8)	
Female	304 (24.3)	129 (24.1)	433 (24.2)	
Race				0.681
White	888 (70.9)	373 (69.6)	1261 (70.5)	
Black	297 (23.7)	129 (24.1)	426 (23.8)	
Other races	67 (5.4)	34 (6.3)	101 (5.6)	
Tumor laterality				0.144
Left	631 (50.4)	268 (50.0)	899 (50.3)	
Right	620 (49.5)	265 (49.4)	885 (49.5)	
Bilateral	1 (0.1)	3 (0.6)	4 (0.2)	
Surgical method				0.404
No surgery	27 (2.2)	10 (1.9)	37 (2.1)	
Cryoablation	37 (3.0)	20 (3.7)	57 (3.2)	
Partial nephrectomy	620 (49.5)	255 (47.6)	875 (48.9)	
Nephroureterectomy	89 (7.1)	51 (9.5)	140 (7.8)	
Radical nephrectomy	479 (38.3)	200 (37.3)	679 (38.0)	

Table 1. Continued

Histological grade				0.379
1	142 (11.3)	60 (11.2)	202 (11.3)	
2	670 (53.5)	281 (52.4)	951 (53.2)	
3	417 (33.3)	178 (33.2)	595 (33.3)	
4	23 (1.8)	17 (3.2)	40 (2.2)	
M stage				0.061
0	1230 (98.2)	519 (96.8)	1749 (97.8)	
1	22 (1.8)	17 (3.2)	39 (2.2)	
N stage				0.063
0	1208 (96.5)	507 (94.6)	1715 (95.9)	
1	44 (3.5)	29 (5.4)	73 (4.1)	
T stage				0.763
1	968 (77.3)	412 (76.9)	1380 (77.2)	
2	135 (10.8)	58 (10.8)	193 (10.8)	
3	146 (11.7)	63 (11.8)	209 (11.7)	
4	3 (0.2)	3 (0.6)	6 (0.3)	
Tumor size (mm)				0.850
≤50	842 (67.3)	358 (66.8)	1200 (67.1)	
>50	410(32.7)	178 (33.2)	588 (32.9)	

3.2. Univariate and multivariate Cox regression analysis

A Cox proportional hazards model was employed for univariate and multivariate analyses on the training set using the competing risks framework. The results indicated that age at diagnosis, surgical method, Fuhrman grade, and TNM stage were independent prognostic factors for Papillary Renal Cell Carcinoma (pRCC) patients ($P < 0.05$; see Table 2). Race, tumor laterality, and tumor size were not significantly associated with overall survival ($P \geq 0.05$). However, sex was included in the multivariate model due to its clinical relevance in prognosis.

Table 2. Univariate and multivariate Cox regression analysis for prognostic factors in pRCC patients

Variable	Univariate Analysis		Multivariate Analysis	
	HR (95%CI)	P Value	HR (95%CI)	P Value
Age				
≤60	1		1	
>60	1.371(1.154~1.562)	<0.001	1.293(1.098~1.452)	<0.001
Sex				
Male	1		1	
Female	0.890(0.678~1.168)	0.401	0.801(0.611~1.063)	0.123
Race				
White	1			
Black	0.813(0.610~1.085)	0.160		
Other races	1.019(0.637~1.629	0.939		
Tumor laterality				
Left	1			
Right	0.954(0.759~1.235)	0.690		
Surgical method				
No surgery	1		1	
Cryoablation	0.383(0.163~0.902)	0.028	0.452(0.202~1.044)	0.063

Table 2. Continued

Partial nephrectomy	0.180(0.095~0.338)	<0.001	0.231(0.133~0.415)	<0.001
Nephroureterectomy	0.510(0.252~1.031)	0.061	0.713(0.372~1.366)	0.308
Radical nephrectomy	0.631(0.343~1.161)	0.139	0.636(0.365~1.082)	0.095
Histological grade				
1	1		1	
2	1.293(0.813~2.058)	0.278	1.205(0.778~1.897)	0.419
3	2.502(1.580~3.963)	<0.001	1.762(1.125~2.760)	0.015
4	5.379(2.863~10.10)	<0.001	2.389(1.223~4.627)	0.011
M stage				
0	1		1	
1	17.84(11.75~27.08)	<0.001	7.492(4.183~11.43)	<0.001
N stage				
0	1		1	
1	9.632(6.921~13.41)	<0.001	2.253(1.378~3.701)	<0.001
T stage				
1	1		1	
2	1.680(1.142~2.472)	0.008	0.892(0.621~1.899)	0.548
3	3.341(2.551~4.375)	<0.001	1.401(1.012~1.943)	0.046
4	23.80(9.650~58.72)	<0.001	0.881(0.293~2.675)	0.819
Tumor size (mm)				
≤50	1			
>50	1.072(0.898~1.176)	0.765		

3.3. Construction of the nomogram model

Based on the five significant prognostic factors identified above, a nomogram model was constructed to predict Cancer-Specific Survival (CSS) in patients with papillary renal cell carcinoma. Each subcategory of the prognostic variables is assigned a score, and the sum of these scores corresponds to a total point score at the bottom of the nomogram. By aligning the total score with the predicted Overall Survival (OS) values, the 1-, 3-, and 5-year survival probabilities can be estimated. (See Figure 1)

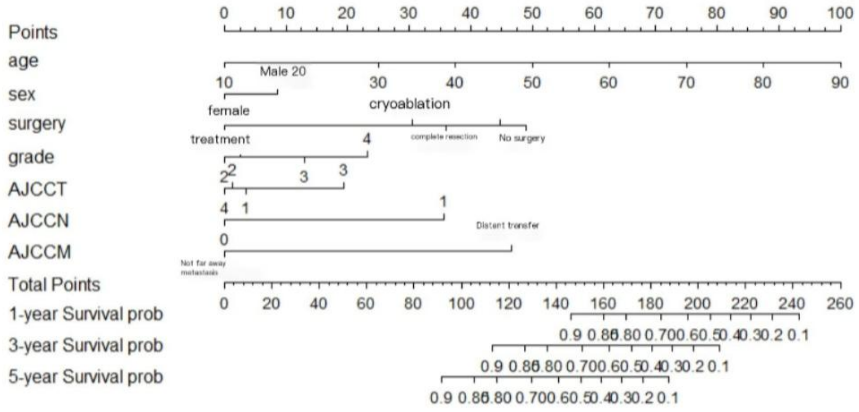
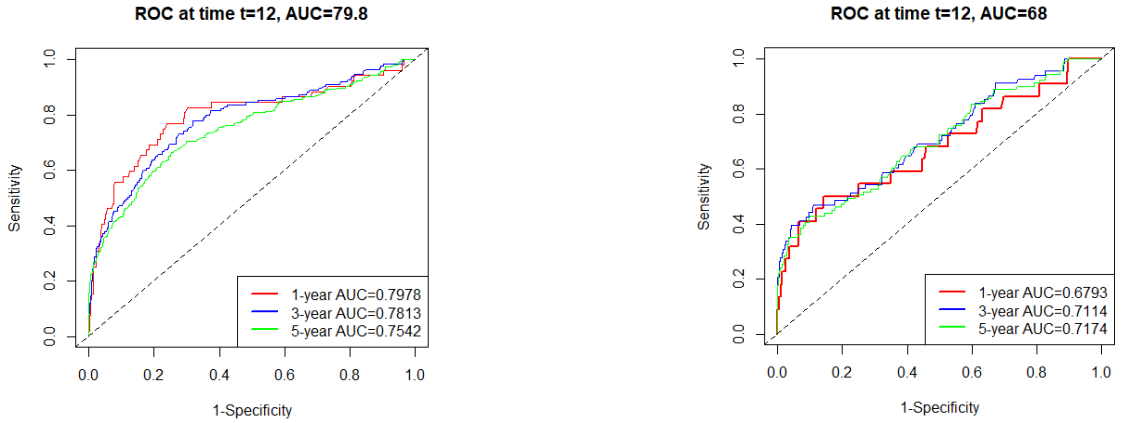


Figure 1. Nomogram for predicting cancer-specific survival in pRCC patients based on the training set

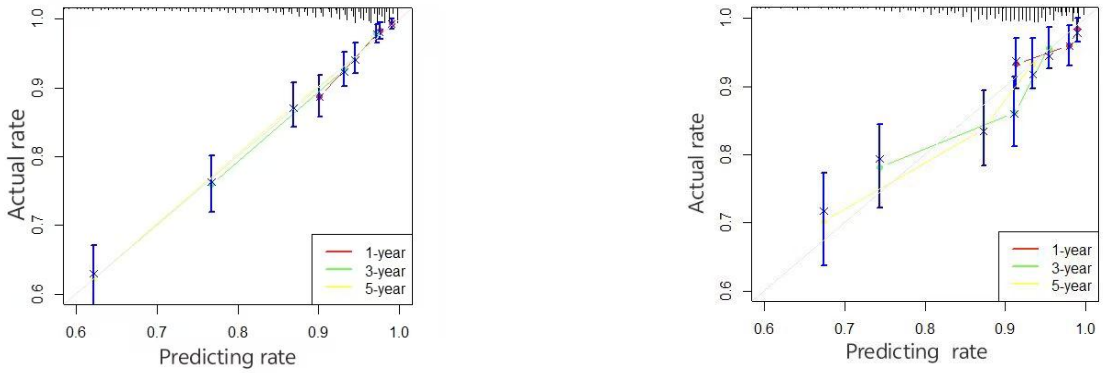
3.4. Validation of the nomogram model

A time-dependent Receiver Operating Characteristic (ROC) curve was plotted with the false positive rate on the x-axis and the true positive rate on the y-axis. The results showed that the Area Under the Curve (AUC) values and 95% confidence intervals (CI) for predicting 1-, 3-, and 5-year survival in the training set were 0.7978 (0.7823–0.8133), 0.7813 (0.7656–0.8030), and 0.7542 (0.7379–0.7705), respectively. For the validation set, the AUC values for the 1-, 3-, and 5-year predictions were 0.6793 (0.6541–0.7045), 0.7114 (0.6856–0.7372), and 0.7174 (0.6918–0.7430), respectively (Figure 2). These results indicate that the model has a certain level of predictive accuracy. The calibration curves demonstrated good agreement between predicted and observed survival probabilities, suggesting that the nomogram provides reliable survival predictions (Figure 3).



(a) (b)

Figure 2. Time-dependent ROC curves for predicting pRCC patient survival in training and validation sets



(a) (b)

Figure 3. Calibration curves for the nomogram model predicting Cancer-Specific Survival (CSS) in training and validation sets

4. Discussion

Papillary Renal Cell Carcinoma (PRCC) is relatively rare in clinical practice, accounting for approximately 18.5% of renal epithelial tumors [4, 5]. Due to limited sample sizes at single centers, it is often difficult to establish a prognostic prediction model for PRCC. Currently, there are relatively few studies on PRCC prognostic models in China. Yan et al. [6], using a large multicenter sample from the SEER database, first identified seven factors (age, T stage, N stage, M stage, surgery/lymph node dissection, and insurance status) that were significantly associated with overall survival, and constructed a prognostic prediction model involving 4,859 patients diagnosed with PRCC between 2010 and 2014. Hu et al. [7] developed a nomogram for predicting postoperative overall survival in patients who underwent either partial or radical nephrectomy, and constructed a new risk assessment system to analyze the differences in survival outcomes between the two procedures. Their findings indicated that patients undergoing partial nephrectomy had better overall survival compared to those receiving radical nephrectomy, possibly due to differences in tumor stage at the time of diagnosis. Zhang et al. [8], recognizing advanced age as an independent prognostic factor for PRCC, constructed a prognostic model for elderly patients using SEER database data. Their univariate and multivariate Cox regression

analyses showed that age, tumor size, histological grade, TNM stage, surgery, radiotherapy, and chemotherapy were all independent prognostic factors, which had a particularly significant impact on elderly patients with PRCC. Haddad et al. [9] found that, among 173 patients with T1a RCC treated with Percutaneous Cryo-Ablation (PCA), cryoablation was a feasible treatment option for those with clinical stage T1a-pRCC. Image-guided percutaneous ablation may be a favorable treatment strategy, particularly for PRCC. Nabavizadeh et al. [10] reported outcomes of 10 cases involving radical nephrectomy and nephroureterectomy for malignant tumors of transplanted allograft kidneys, showing good long-term survival after surgery. There was also a case report of a patient who underwent nephroureterectomy and experienced recurrent bladder PRCC metastasis, though prognosis was poor due to distant metastasis [11]. In addition to traditional surgical approaches, prospective clinical trials have shown that immune checkpoint inhibitors exhibit certain therapeutic activity in PRCC [12]. However, although many of these surgical approaches have been clinically proven to improve prognosis in PRCC patients, no studies have yet developed a unified clinical prognostic prediction model to analyze long-term survival outcomes for patients undergoing different surgical treatments. Therefore, this study aims to establish a tool for evaluating disease-specific survival CSS outcomes among PRCC patients undergoing different surgical procedures, based on clinicopathological information from the SEER database. Despite some limitations of the SEER database—such as underrepresentation of Asian populations and partial missing clinical data—race is generally not considered to be significantly associated with CSS in PRCC. Moreover, the SEER database covers a broad patient population, which helps reduce bias compared to single-center or small-sample datasets. Thus, this study provides a potentially useful reference for clinicians and PRCC patients in making prognostic decisions. Nevertheless, as external validation was not performed in this study, the model's generalizability may be limited. Further prospective studies are needed to validate the current findings.

Funding

The Key Joint Project of the Hunan Provincial Natural Science Foundation and Municipal Science Foundation (2024JJ7428)

References

[1] Bahadoram, S., Davoodi, M., Hassanzadeh, S. (2022). Renal cell carcinoma: an overview of the epidemiology, diagnosis, and treatment. *G Ital Nefrol, 39*(3).

[2] Angori, S., Lobo, J., & Moch, H. (2022). Papillary renal cell carcinoma: current and controversial issues. *Curr Opin Urol, 32*(4), 344-351.

[3] Doll, K. M., Rademaker, A., & Sosa, J. A. (2018). Practical Guide to Surgical Data Sets: Surveillance, Epidemiology, and End Results (SEER) Database. *JAMA Surg, 153*(6), 588-589.

[4] Caraballo, B., Abdulla, M., Sham, S. (2022). Papillary Renal Cell Carcinomas Demonstrating Micropapillary Features: An Investigation Into the Diagnostic and Prognostic Implications. *Cureus, 14*(5), e24944.

[5] Qian, X., Wan, J., Qian, C. (2021). Clinicopathological Features and Prognostic Outcomes of Papillary Renal Cell Carcinoma. *Int J Gen Med, 14*, 7523-7531.

[6] Yan, H., Wei, X., Wu, A. (2020). Nomograms for predicting overall and cancer-specific survival in patients with papillary renal cell carcinoma: a population-based study using SEER database. *Transl Androl Urol, 9*(3), 1146-1158.

[7] Hu, Y., Xu, S., Qi, Q. (2022). A novel nomogram and risk classification system predicting the overall survival of patients with papillary renal cell carcinoma after nephrectomy: A population-based study. *Front Public Health, 10*, 989566.

[8] Zhanghuang, C., Wang, J., Yao, Z. (2022). Development and Validation of a Nomogram to Predict Cancer-Specific Survival in Elderly Patients With Papillary Renal Cell Carcinoma. *Front Public Health, 10*, 874427.

[9] Haddad, M. M., Schmit, G. D., Kurup, A. N. (2018). Percutaneous Cryoablation of Solitary, Sporadic Renal Cell Carcinoma: Outcome Analysis Based on Clear-Cell versus Papillary Subtypes. *J Vasc Interv Radiol, 29*(8), 1122-1126.

[10] Nabavizadeh, R., Nooralia, A. A., Makhani, S. S. (2020). Transplant Radical Nephrectomy and Transplant Radical Nephroureterectomy for Renal Cancer: Postoperative and Survival Outcomes. *Ann Transplant, 25*, e925865.

[11] Zeng, Q., Luo, S., Chen, L. (2023). Bladder metastasis from type 2 papillary renal cell carcinoma: A case report. *Oncol Lett, 25*(6), 270.

[12] Maughan, B. L., & Sirohi, D. (2023). Papillary Renal Cell Carcinoma: A Review of Prospective Clinical Trials. *Curr Treat Options Oncol, 24*(9), 1199-1212.