Current Science
CS 5 (3), 2887-2895 (2025)
Received 20 March 2025 | **Revised 10 April** 2025 | **Accepted 20 May**. 2025 | **Online Available 08 June** 2025
https://doi.org/ 10.52845/CS/2025-5-3-63

Current Science

Current Science

OPEN ACCESS

ISSN(O)2795-8639

Original Article

Trends and Outcomes in Renal Cell Carcinoma: A Decade of Evidence from a Single Center

Zhang, Longlong MD [1,†]; Zhang,Yifan MD [1,†]; Fan, Xiaozheng MD [1,†]; Hou, Haozhong MD [2,†]; Quan, Penghe MD [1,†]; Qi, Zhengxiang MD [1,†]; Shi, XinYu MD [1,†]; Dong, Mohan MD [3*]; Yang, Xiaojian MD [1,*]

[1]Department of Urology, Xijing Hospital, Air Force Military Medical University, Xi'an, Shanxi, China

[2]Department of Urology, Tangdu Hospital, Air Force Military Medical University, Xi'an, Shanxi, China

[3]Medical Affairs Office, Xijing Hospital, Air Force Military Medical University, Xi'an, Shanxi, China

[†]These authors have contributed equally to this work

[*]Corresponding Author: Dong Mohan , Yang Xiaojian

Abstract:

Background: Renal cell carcinoma (RCC) remains a significant urological cancer with diverse treatment outcomes based on clinical and pathological factors. This study provided a comprehensive decade-long analysis of RCC management, focusing on evolving surgical techniques and their impact on prognosis.

Methods: A retrospective cohort study was conducted involving 950 patients with RCC who underwent surgery between 2009 and 2017. Data collection included demographic details, surgical methods (open surgery, laparoscopy, and robot-assisted laparoscopy), and follow-up outcomes. Statistical analyses included Kaplan-Meier survival curves and Cox regression models to evaluate the prognostic impact of various clinical and pathological variables.

Results: A total of 950 patients were included in the study (mean age: 55.92 years). The study highlighted the significant survival advantages associated with minimally invasive surgical techniques. Robot-assisted laparoscopic approaches showed superior survival rates compared to open surgeries ($p < 0.05$). Multivariate regression analyses demonstrated that key prognostic factors impacting survival included age (HR =1.04, $p = 0.006$), RCC subtype (HR = 6.523, $p < 0.001$), sarcoma-like lesion (HR =3.90, $p = 0.015$) and hemoglobin (HR =0.98, $p = 0.017$).

Conclusion: This extensive analysis confirmed that surgical innovation in RCC treatment significantly enhances patient outcomes. Our study not only showed taht the shift towards minimally invasive surgery aligns with improved survival rates but also highlights important prognostic factors based on the patient. These findings advocate continued advancements in surgical techniques and a deeper understanding of RCC prognostic factors to optimize treatment strategies.

Keywords: Renal cell carcinoma; open nephrectomy; laparoscopic nephrectomy; robot-assisted laparoscopic nephrectomy

1. Introduction

With 431,288 new cases and 179,368 annual deaths reported in the 2020 GLOBOCAN statistics, the incidence and mortality of renal cancer are continually increasing [1]. As the most prevalent type of kidney cancer in adults, RCC is characterized by a high degree of biological heterogeneity, which complicates its clinical management and outcome predictions[2]. Recent decades have witnessed significant shifts in the

diagnostic and therapeutic landscapes of RCC, primarily owing to advancements in imaging technologies and surgical techniques[3,4].

The majority of RCC cases are diagnosed incidentally through imaging studies conducted for other medical reasons, owing to the asymptomatic nature of early-stage disease[5]. This incidental detection has progressively shifted the clinical stage at diagnosis towards localized disease, which is amenable to surgical intervention. Surgery remains the cornerstone of curative treatment for localized RCC, with techniques ranging from traditional open nephrectomy to minimally invasive approaches such as laparoscopic and robot-assisted surgery[6,7].Despite advancements in surgical methods, the choice of surgical approach significantly influences outcomes. Minimally invasive techniques have been associated with reduced perioperative morbidity, shorter hospital stays, and faster recovery times compared to open surgery[8]. Furthermore, the evolution of robot-assisted surgeries has introduced greater precision and flexibility, potentially increasing the oncological safety of complex RCC cases[9].

However, the prognosis of RCC is not determined solely by the choice of surgical technique. Several prognostic factors, including patient age, tumor stage, histological subtype, and presence of symptoms at diagnosis, play crucial roles in determining overall survival and recurrence rates[10,11]. The heterogeneity of RCC, with its various subtypes such as clear cell, papillary, and chromophobe RCC, presents unique challenges and responds differently to surgical interventions[12].

The study conducted at a single center spans neatly a decade (2009-2017) and offers a comprehensive analysis of RCC treatments, focusing on the outcomes associated with different surgical techniques and their impact on long-term patient survival. This longitudinal analysis is crucial as it reflects real-world practices and outcomes, contributing to ongoing discussions on optimizing RCC management. The incorporation of advanced statistical tools such as the Kaplan-Meier method and Cox regression models in this study allows for a nuanced understanding of survival outcomes and the influence of various prognostic factors. These models are pivotal in assessing the effectiveness of different surgical approaches over time and in a large patient cohort, providing evidence-based insights that could guide future clinical decisions[13].

In summary, the evolving surgical landscape for RCC presents both opportunities and challenges. Understanding the interplay between surgical innovations and traditional prognostic factors is essential for tailoring treatment strategies to maximize patient outcomes. This study aimed to bridge gaps in knowledge regarding the prognostic impacts of surgical techniques in RCC, emphasizing the importance of personalized treatment approaches based on comprehensive clinical and pathological evaluations[14].

Materials and Methods

Study Design and Population

This retrospective cohort study included patients diagnosed with renal cell carcinoma (RCC) treated at our Hospital between January 2009 and December 2017. Patients eligible for inclusion were those who underwent surgical intervention for RCC and had complete medical records for analysis. Patients were excluded if they had metastatic disease at diagnosis or incomplete follow-up data.

Data Collection

Clinical data were extracted from the hospital's electronic health records system. The collected variables included demographic information (age, sex, residential status), clinical presentation (symptoms at diagnosis), surgical details (type of surgery, operative approach), and pathological data (RCC subtype, stage, and grade). Survival data were obtained from follow-up records up to October 2018.

Surgical Techniques

Patients were grouped based on the surgical technique employed:

Open Nephrectomy (ON): Traditional open surgical approach.

Laparoscopic Nephrectomy (LN): Minimally invasive approach using small incisions and specialized instruments.

Robot-Assisted Laparoscopic Nephrectomy (RALN): Advanced minimally invasive approach utilizing robotic technology.

Statistical Analysis

Descriptive statistics were used to summarize demographic and clinical characteristics. Survival outcomes were analyzed using the Kaplan-Meier method, and survival curves were generated for visual comparison of survival rates across different surgical techniques. The log-rank test was used to compare survival distributions. Multivariable Cox proportional hazards models were constructed to identify independent prognostic factors affecting overall survival. Variables included in the model were age, sex, clinical stage, RCC subtype, surgical technique, and symptomatology, etc. Results were presented as hazard ratios (HRs) with 95% confidence intervals (CIs). All statistical tests were 2-sided, and a p value < 0.05 was considered statistically significant.

Ethical Considerations

This study was performed in accordance with the ethical standards of the Declaration of Helsinki (1964) and its subsequent amendments. The experiments were approved by the Medical Ethics Committee of the Xijing Hospital.

Results

Patient Demographics and Clinical Characteristics

This study evaluated 950 patients diagnosed with renal cell carcinoma (RCC). The demographic breakdown showed a higher prevalence of RCC in males (67.1%) and the mean age of diagnosis at 55.92 years. Most of patients resided in urban areas (70.1%). More than half of the patients(68.3%) operated on had no visible symptoms. Clear cell carcinoma was predominant in the RCC subtypes, accounting for 86.7% of cases, with papillary and chromophobe types comprising 4.8% and 3.9%, respectively. The demographic and clinical profiles are summarized in Table 1.

Table 1: Demographic and Clinical Characteristics of the Study Population.

	Level	Overall	ON	LN	RALN	*p*
N		950	525	257	168	
Gender	Female	313 (32.9)	181 (34.5)	84 (32.7)	48 (28.6)	0.364
	Male	637 (67.1)	344 (65.5)	173 (67.3)	120 (71.4)	
Age		55.92 (11.98)	55.94 (11.78)	55.86 (12.08)	55.94 (12.54)	0.995
Weight		68.31 (12.36)	68.28 (12.78)	67.86 (11.76)	69.10 (11.95)	0.6
Resident	Country	284 (29.9)	164 (31.2)	84 (32.7)	36 (21.4)	0.028
	Urban	666 (70.1)	361 (68.8)	173 (67.3)	132 (78.6)	
Smoking	No	723 (76.1)	395 (75.2)	207 (80.5)	121 (72.0)	0.103
	Yes	227 (23.9)	130 (24.8)	50 (19.5)	47 (28.0)	
Drinking	No	839 (88.3)	459 (87.4)	241 (93.8)	139 (82.7)	0.002
	Yes	111 (11.7)	66 (12.6)	16 (6.2)	29 (17.3)	
Diabetes	No	846 (89.1)	470 (89.5)	232 (90.3)	144 (85.7)	0.296
	Yes	104 (10.9)	55 (10.5)	25 (9.7)	24 (14.3)	
Hypertension	No	663 (69.8)	366 (69.7)	182 (70.8)	115 (68.5)	0.873
	Yes	287 (30.2)	159 (30.3)	75 (29.2)	53 (31.5)	
Symptom	No	649 (68.3)	363 (69.1)	158 (61.5)	128 (76.2)	0.005
	Yes	301 (31.7)	162 (30.9)	99 (38.5)	40 (23.8)	
Surgery	Ablation	2 (0.2)	1 (0.2)	1 (0.4)	0 (0.0)	<0.001
	NSS	376 (39.6)	164 (31.2)	62 (24.1)	150 (89.3)	
	RN	572 (60.2)	360 (68.6)	194 (75.5)	18 (10.7)	
RABT		7.64 (13.30)	6.78 (11.98)	3.91 (8.72)	16.08 (18.55)	<0.001
Pathlogy	ccRCC	824 (86.7)	467 (89.0)	211 (82.1)	146 (86.9)	0.075
	chRCC	46 (4.8)	26 (5.0)	15 (5.8)	5 (3.0)	
	Others	37 (3.9)	14 (2.7)	16 (6.2)	7 (4.2)	
	pRCC	43 (4.5)	18 (3.4)	15 (5.8)	10 (6.0)	

SL	No	931 (98.0)	515 (98.1)	248 (96.5)	168 (100.0)	0.041
	Yes	19 (2.0)	10 (1.9)	9 (3.5)	0 (0.0)	
Ncrosis	No	878 (92.4)	480 (91.4)	236 (91.8)	162 (96.4)	0.094
	Yes	72 (7.6)	45 (8.6)	21 (8.2)	6 (3.6)	
Thrombus	No	929 (97.8)	516 (98.3)	245 (95.3)	168 (100.0)	0.003
	Yes	21 (2.2)	9 (1.7)	12 (4.7)	0 (0.0)	
T	I/II	920 (96.8)	510 (97.1)	242 (94.2)	168 (100.0)	0.003
	III/IV	30 (3.2)	15 (2.9)	15 (5.8)	0 (0.0)	
N	0	934 (98.3)	518 (98.7)	248 (96.5)	168 (100.0)	0.015
	1	16 (1.7)	7 (1.3)	9 (3.5)	0 (0.0)	
M	0	922 (97.1)	513 (97.7)	244 (94.9)	165 (98.2)	0.061
	1	28 (2.9)	12 (2.3)	13 (5.1)	3 (1.8)	
Stage	I/II	891 (93.8)	495 (94.3)	231 (89.9)	165 (98.2)	0.002
	III/IV	59 (6.2)	30 (5.7)	26 (10.1)	3 (1.8)	
NLR		2.64 (1.90)	2.60 (2.00)	2.76 (1.82)	2.60 (1.69)	0.497
Hemoglobin		139.18 (26.92)	139.29 (26.57)	137.00 (27.11)	142.16 (27.56)	0.154
Platelet		212.35 (78.20)	214.47 (79.71)	216.39 (82.78)	199.46 (63.96)	0.06
Albumin		43.80 (6.76)	43.84 (7.62)	43.46 (5.81)	44.19 (5.08)	0.541

Abbreviation: RN, radical nephrectomy; NSS, nephron sparing surgery; RABT: Renal artery blockade time; SL, sarcoma-like lesion; NLR, neutrophil/lymphocyte ratio.
Continuous variables were presented as mean (SE); Categorical variables were presented as N (%).

Surgical Techniques and Operative Details

Surgical interventions were distributed among Laparoscopic Nephrectomy (LN, 55.3%), Open Nephrectomy (ON, 27.1%), and Robot-Assisted Laparoscopic Nephrectomy (RALN, 17.6%). The trend towards minimally invasive surgeries increased notably during the latter part of the study period, aligning with advancements in surgical technologies and enhanced recovery protocols (Figure 1).

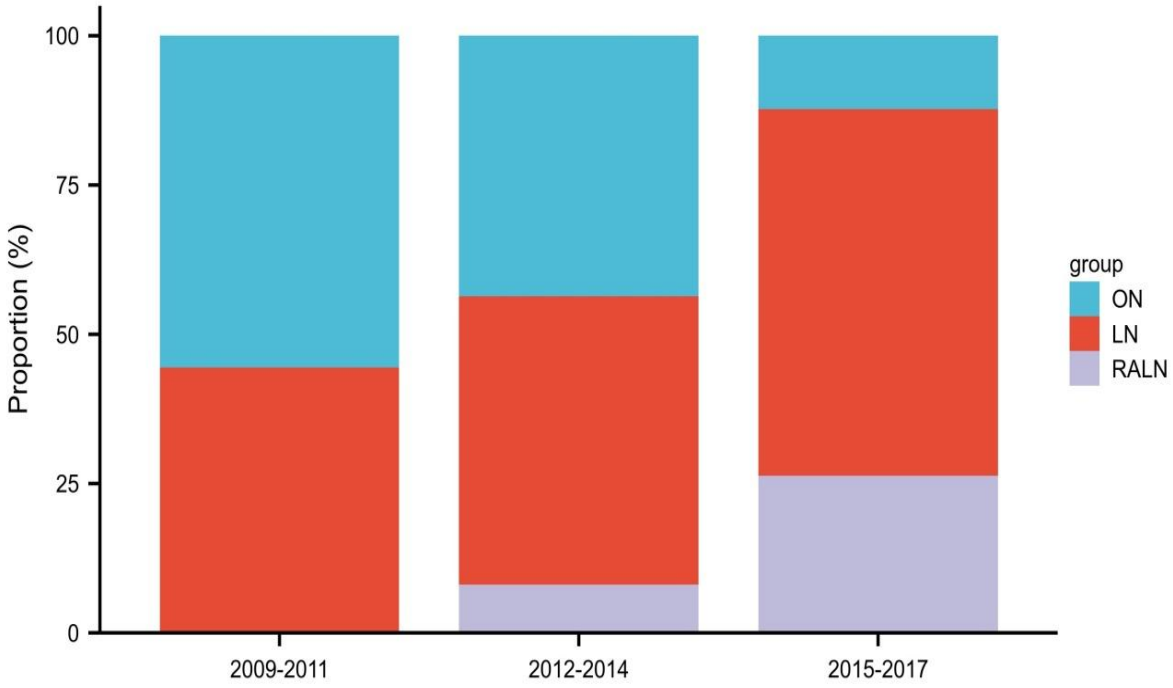

Figure 1 Trend chart of changes in surgical techniques for patients with RCC.

Survival Outcomes

Kaplan-Meier survival analysis showed significant variability in survival outcomes based on the surgical method employed. Patients had a five-year survival rate of about 90%, with patients in the RALN and LN groups having a better five-year survival rate compared to ON. The survival curves distinctly favored minimally invasive approaches, particularly robotic assistance, which is depicted in Figure 2.

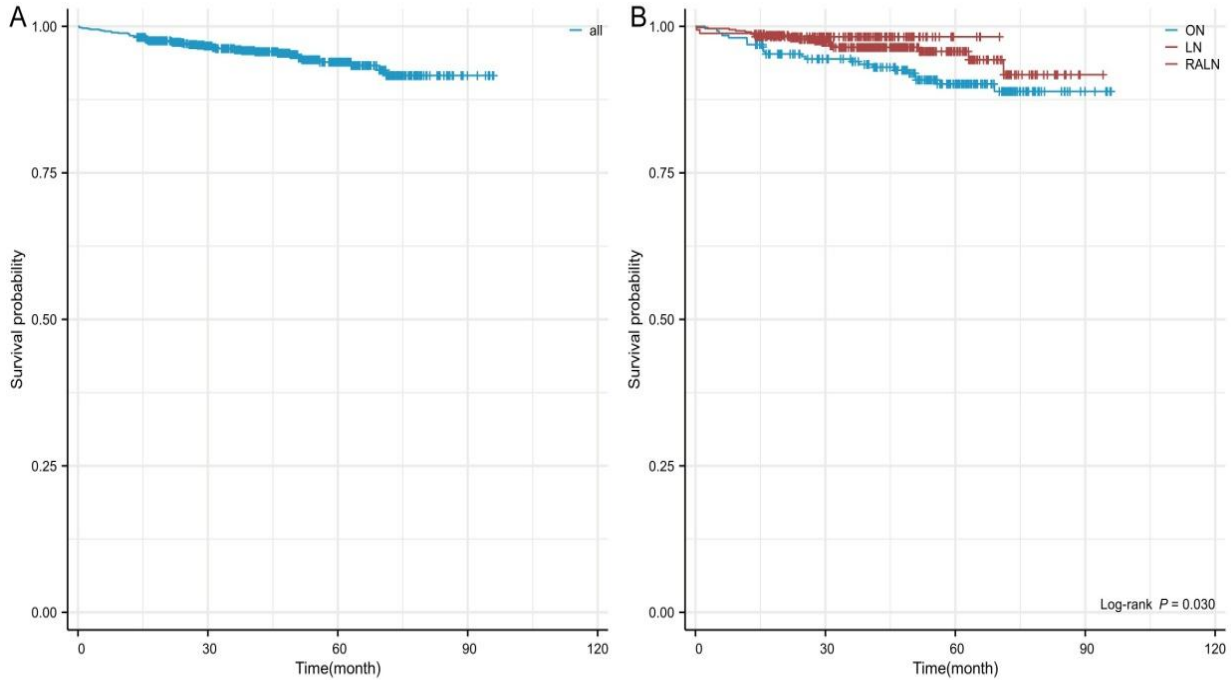

Figure 2 The survival curves of RCC patients. A. The survival curves of all RCC patients. B. The survival curves of RCC patients grouped by surgical techniques.

Multivariate Cox Proportional Hazards Model

On multivariate analysis, several factors were identified as significant predictors of survival (Table 2). Advanced age increased the risk of mortality (HR 1.04, 95% CI 1.01-1.07, $p = 0.006$). At the same time, patients living in rural areas had a significantly worse prognosis than those in urban areas (HR 2.11, 95% CI 1.04-4.25, $p = 0.038$). And compared to clear cell carcinoma, papillary cell carcinoma appears to demonstrate a worse clinical prognosis (HR 6.52, 95% CI 2.74-15.5, $p < 0.001$). If the tumour histopathology is accompanied by sarcoma-like lesion, this also predicts a worse outcome (HR 3.91, 95% CI 1.31-11.66, $p = 0.015$). In contrast, hemoglobin levels were associated with better patient prognosis (HR 0.99, 95% CI 0.98-1.00, $p = 0.017$).

Table 2. Cox regression analysis to explore prognostic indicators of RCC.

Characteristics	Total (N)	Univariate analysis		Multivariate analysis	
		Hazard ratio (95% CI)	*P value*	Hazard ratio (95% CI)	*P value*
Age	950	1.038 (1.012 - 1.065)	**0.004**	1.043 (1.012 - 1.075)	**0.006**
Weight	950	0.963 (0.938 - 0.989)	**0.006**	0.999 (0.969 - 1.030)	0.969
Resident	950				
Urban	666	Reference		Reference	
Country	284	2.136 (1.189 - 3.838)	**0.011**	2.105 (1.042 - 4.254)	**0.038**
Symptom	950				
No	649	Reference		Reference	
Yes	301	2.893 (1.606 - 5.211)	**< 0.001**	1.563 (0.802 - 3.046)	0.189
Surgery	950				

RN	572	Reference		Reference	
NSS	376	0.280 (0.118 - 0.664)	**0.004**	0.710 (0.164 - 3.079)	0.647
Ablation	2	0.000 (0.000 - Inf)	0.996	0.000 (0.000 - Inf)	0.997
Surgical technique	950				
ON	257	Reference		Reference	
LN	525	0.512 (0.276 - 0.949)	**0.034**	0.710 (0.368 - 1.371)	0.307
RALN	168	0.299 (0.089 - 1.010)	0.052	0.915 (0.177 - 4.724)	0.915
RABT	947	0.935 (0.889 - 0.984)	**0.009**	0.956 (0.878 - 1.042)	0.308
Pathology	950				
ccRCC	824	Reference		Reference	
chRCC	46	1.209 (0.289 - 5.061)	0.795	1.305 (0.298 - 5.724)	0.724
pRCC	43	8.705 (4.227 - 17.924)	< **0.001**	6.523 (2.743 - 15.510)	<**0.001**
Others	37	2.233 (0.681 - 7.323)	0.185	2.068 (0.571 - 7.489)	0.268
SL	950				
No	931	Reference		Reference	
Yes	19	13.951(6.183 - 31.479)	< **0.001**	3.906 (1.308 - 11.664)	**0.015**
Necrosis	950				
No	878	Reference		Reference	
Yes	72	4.497 (2.207 - 9.166)	< **0.001**	1.222 (0.502 - 2.974)	0.659
Thrombus	950				
No	929	Reference		Reference	
Yes	21	6.765 (2.666 - 17.164)	< **0.001**	1.787 (0.475 - 6.728)	0.391
T	950				
I/II	920	Reference		Reference	
III/IV	30	9.567 (4.424 - 20.690)	< **0.001**	0.993 (0.237 - 4.170)	0.993
N	950				
0	934	Reference		Reference	
1	16	19.450 (8.966 - 42.193)	< **0.001**	1.999 (0.517 - 7.729)	0.316
M	950				
0	922	Reference		Reference	
1	28	8.671 (4.030 - 18.656)	< **0.001**	1.473 (0.459 - 4.724)	0.515
Stage	950				
I/II	891	Reference		Reference	
III/IV	59	11.618 (6.262 - 21.556)	<**0.001**	3.967 (0.908 - 17.327)	0.067
NLR	950	1.130 (1.073 - 1.191)	<**0.001**	1.089 (0.995 - 1.192)	0.063
Hemoglobin	950	0.987 (0.980 - 0.994)	< **0.001**	0.987 (0.976 - 0.998)	**0.017**
Platelet	949	1.003 (1.001 - 1.005)	**0.009**	1.001 (0.997 - 1.005)	0.603
Albumin	950	0.963 (0.935 - 0.991)	**0.011**	1.008 (0.968 - 1.049)	0.713

Abbreviation: RN, radical nephrectomy; NSS, nephron sparing surgery; RABT: Renal artery blockade time; SL, sarcoma-like lesion; NLR, neutrophil/lymphocyte ratio.

Discussion

This retrospective cohort study of 950 renal cell carcinoma (RCC) patients treated at a single center over a decade provides a significant insight into the evolving landscape of RCC treatment. The transition from open nephrectomy (ON) to minimally invasive techniques such as laparoscopic nephrectomy (LN) and robot-assisted laparoscopic nephrectomy (RALN) reflects

broader trends in oncological surgery that prioritize patient recovery and long-term outcomes[15].

Surgical Outcomes and Prognostic Factors

The survival outcomes reported in our study are consistent with the literature, which suggests that minimally invasive surgical techniques offer advantages in terms of reduced perioperative morbidity and enhanced recovery, without compromising the oncological efficacy[16]. Our findings that RALN patients had the highest five-year survival rate and significantly lower risk of mortality align with previous studies highlighting the benefits of robotic assistance in surgical precision and minimizing physical trauma[17,18]. This supports the argument for the broader adoption of RALN in RCC treatment, particularly for clear cell carcinoma, the most common and aggressive subtype of RCC.

Furthermore, our multivariate analysis identified several key prognostic factors affecting survival, including age, clinical stage, and symptoms at diagnosis. These factors are well-documented in RCC literature as critical determinants of patient prognosis[11]. The strong correlation between advanced clinical stage and poorer outcomes underscores the importance of early detection and intervention in RCC management. Additionally, the presence of symptoms at diagnosis being linked to poorer survival outcomes suggests that symptomatic patients may have more advanced disease at presentation, which is a known adverse prognostic factor[19].

Technological Advancements in Surgical Practice

The significant survival benefit associated with RALN may be attributed to technological advancements that allow for more precise tumor removal with minimal impact on healthy tissues. Robotic systems enhance dexterity and provide 3D visualization, which potentially increases the likelihood of complete tumor resection and decreases the risk of local recurrence[20]. These advantages are particularly pertinent in managing complex cases where tumor anatomy or location might limit the efficacy of traditional laparoscopic approaches[21].

Implications for Clinical Practice

The implications of these findings are profound for clinical practice. They advocate for a personalized approach to RCC treatment, where surgical techniques are tailored not only to the disease stage and patient characteristics but also to the histological subtype of the tumor. Furthermore, our study reinforces the need for ongoing training and adaptation among surgical teams to keep pace with technological advancements and integrate them into routine practice[22].

Limitations and Future Directions

Despite its strengths, this study is not without limitations. The retrospective design and single-center nature may introduce selection bias and limit the generalizability of the findings. Prospective multicenter trials are needed to validate these results and potentially explore the long-term cost-effectiveness of robotic versus traditional surgical approaches. Additionally, further research into the molecular biology of RCC could enhance the understanding of subtype-specific responses to different surgical techniques.

Conclusion

In conclusion, this study contributes to the evolving paradigm in RCC treatment, where technological innovation in surgery is matched with a deep understanding of the disease's biological behavior. It underscores the significance of personalized treatment strategies that consider the interplay of surgical technique, patient demographics, and tumor pathology to optimize outcomes.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

Conceptualization: Zhang, Longlong; Zhang, Yifan

Data Curation: Fan, Xiaozheng; Hou, Haozhong; Quan, Penghe.

Formal Analysis: Hou, Haozhong; Quan, Penghe.

Funding Acquisition: Zhang, Longlong.

Investigation: Zhang, Longlong; Hou, Haozhong.

Project Administration: Fan, Xiaozheng.

Supervision: Dong, Mohan; Yang, Xiaojian.

Writing – original draft: Zhang, Longlong; Fan, Xiaozheng; Hou, Haozhong; Quan, Penghe.

Writing – review & editing: Dong, Mohan; Yang, Xiaojian.

Funding

This study is supported by the Xijing Hospital Discipline Advancement Project (XJZT24CY28).

Acknowledgments

The authors would like to thank all the medical staff who participated in this study, as well as the patients.

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

References

1. Sung H, Ferlay J, Siegel RL, et al. Global Cancer Statistics 2020: GLOBOCAN Estimates of Incidence and Mortality Worldwide for 36 Cancers in 185 Countries. *CA Cancer J Clin.* 2021;71(3):209-249.
2. Armstrong AJ, Halabi S, Eisen T, et al. Everolimus versus sunitinib for patients with metastatic non-clear cell renal cell carcinoma (ASPEN): a multicentre, open-label, randomised phase 2 trial. *Lancet Oncol.* 2016;17(3):378-388.
3. Wu R, Wang K, Gai Y, et al. Nanomedicine for renal cell carcinoma: imaging, treatment and beyond. *J Nanobiotechnology.* 2023;21(1):3.
4. Hsieh JJ, Purdue MP, Signoretti S, et al. Renal cell carcinoma. *Nat Rev Dis Primers.* 2017;3:17009.
5. Johnson DC, Vukina J, Smith AB, et al. Preoperatively misclassified, surgically removed benign renal masses: a systematic review of surgical series and United States population level burden estimate. *J Urol.* 2015;193(1):30-35.
6. Smith ZL. Current Status of Minimally Invasive Surgery for Renal Cell Carcinoma. *Curr Urol Rep.* 2016;17(6):43.
7. Ljungberg B, Albiges L, Abu-Ghanem Y, et al. European Association of Urology Guidelines on Renal Cell Carcinoma: The 2022 Update. *Eur Urol.* 2022;82(4):399-410.
8. MacLennan S, Imamura M, Lapitan MC, et al. Systematic review of oncological outcomes following surgical management of localised renal cancer. *Eur Urol.* 2012;61(5):972-993.
9. Masson-Lecomte A, Bensalah K, Seringe E, et al. A prospective comparison of surgical and pathological outcomes obtained after robot-assisted or pure laparoscopic partial nephrectomy in moderate to complex renal tumours: results from a French multicentre collaborative study. *BJU Int.* 2013;111(2):256-263.
10. Pajunen H, Veitonmäki T, Huhtala H, Nikkola J, Pöyhönen A, Murtola T. Prognostic factors of renal cell cancer in elderly patients: a population-based cohort study. *Sci Rep.* 2024;14(1):6295.
11. Klatte T, Rossi SH, Stewart GD. Prognostic factors and prognostic models for renal cell carcinoma: a literature review. *World J Urol.* 2018;36(12):1943-1952.
12. Nocera L, Collà Ruvolo C, Stolzenbach LF, et al. Tumor Stage and Substage Predict Cancer-specific Mortality After Nephrectomy for Non metastatic Renal Cancer: Histological Subtype-specific Validation. *Eur Urol Focus.* 2022;8(1):182-190.
13. Craddock M, Crockett C, McWilliam A, et al. Evaluation of Prognostic and Predictive Models in the Oncology Clinic. *Clin Oncol (R Coll Radiol).* 2022;34(2):102-113.
14. Larcher A, Wallis CJD, Bex A, et al. Individualised Indications for Cytoreductive Nephrectomy: Which Criteria Define the Optimal Candidates? *Eur Urol Oncol.* 2019;2(4):365-378.
15. Are C, Murthy SS, Sullivan R, et al. Global Cancer Surgery: pragmatic solutions to improve cancer surgery outcomes worldwide. *Lancet Oncol.* 2023;24(12):e472-e518.
16. Calpin GG, Ryan FR, McHugh FT, McGuire BB. Comparing the outcomes of open, laparoscopic and robot-assisted partial nephrectomy: a network meta-analysis. *BJU Int.* 2023;132(4):353-364.
17. Vartolomei MD, Matei DV, Renne G, et al. Robot-assisted Partial Nephrectomy: 5-yr Oncological Outcomes at a Single European Tertiary Cancer Center. *Eur Urol Focus.* 2019;5(4):636-641.
18. Andrade HS, Zargar H, Caputo PA, et al. Five-year Oncologic Outcomes After Transperitoneal Robotic Partial Nephrectomy for Renal Cell Carcinoma. *Eur Urol.* 2016;69(6):1149-1154.
19. Vasudev NS, Wilson M, Stewart GD, et al. Challenges of early renal cancer detection: symptom patterns and incidental diagnosis rate in a

multicentre prospective UK cohort of patients presenting with suspected renal cancer. *BMJ Open.* 2020;10(5):e035938.
20. Otaola-Arca H, Krebs A, Bermúdez H, et al. Long-Term Oncological and Functional Outcomes After Robot-Assisted Partial Nephrectomy for Clinically Localized Renal Cell Carcinoma. *Ann Surg Oncol.* 2022;29(4):2484-2494.
21. Liu Z, Zhang X, Lv P, Wu B, Bai S. Functional, oncological outcomes and safety of laparoscopic partial nephrectomy versus open partial nephrectomy in localized renal cell carcinoma patients with high anatomical complexity. *Surg Endosc.* 2022;36(10):7629-7637.
22. Hussain Z. Adopting new technology is crucial to surgeons' training, says report. *Bmj.* 2022; 378:o1989.

Abbreviations:

RCC: Renal cell carcinoma

ON: Open nephrectomy

LN: Laparoscopic nephrectomy

RALN: Robot-assisted laparoscopic nephrectomy

HRs: Hazard ratios

CIs: Confidence intervals

CcRCC: Clear cell renal cell carcinoma

Prcc: Papillary renal cell carcinoma

chRCC: Chromophobe renal cell carcinoma