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Treatment Modalities and Risks of Complication for Patients With Localized Renal Cell Carcinoma Aged 75 and Older

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ABSTRACT

Background and Objectives: Partial (PN)/radical (RN) nephrectomy is the standard treatment for localized renal-cell carcinoma (RCC). The potential risks of these procedures are concerns for the elderly. We evaluated perioperative outcomes/survival for patients aged ≥ 75 years with localized RCC who underwent PN, RN, or thermal ablation (TA).

Methods: Localized RCC patients undergoing PN/RN/TA (2000–2023) were retrospectively reviewed. Logistic-regression assessed factors associated with major complications. Kaplan-Meier estimated survival.

Results: A total of 278 patients (≥ 75 years) with RCC who received intervention (107RN, 101PN, and 70TA) were identified. Median age was 78 years. PN patients were younger than other cohorts (77 vs. 79, $p = 0.006$). Patients with cancer comorbidities underwent TA than PN/RN (93% vs. 88%/76%, respectively). Median tumor size was 4.0, 3.0, and 2.6 cm in RN, PN, and TA cohorts, respectively. RN patients had more complex masses compared to other cohorts (9 vs. 7, $p < 0.001$). Postoperative complications were significantly greater among PN patients ($p = 0.03$), but there was no significant difference in Clavien ≥ 3 complications. Peripheral vascular disease (PVD) was associated with Clavien ≥ 3 complications on multivariable analysis ($p = 0.03$). RN was performed at a stable rate while PN decreased in favor of TA. There was no significant difference in RCC-/non-RCC-specific survival among treatment modalities.

Conclusions: It is important to make informed decisions about treating RCC in the elderly to reduce morbidity/mortality. PVD could be a determining factor favoring TA for amenable tumors.

1 | Introduction

Renal cell carcinoma (RCC) is the seventh most common cancer in the United States, accounting for 2% of all cancer diagnoses globally [1, 2]. Median age of diagnosis is 65 years with 5-year relative survival of 77.6% [2]. The American Cancer Society estimated about 81,610 new kidney cases would be diagnosed and about 14,390 patients would die from the disease in 2024 [3]. With the increase in life expectancy and widespread use of cross-sectional imaging, renal masses are being incidentally detected, particularly in patients aged between 70 and 89 [4–6]. Hence, localized disease accounts for the majority of RCC cases [2].

Abbreviations: AUA, American Urological Association; BMI, body mass index; CAD, coronary artery disease; CKD, chronic kidney disease; CKD-EPI, chronic kidney disease epidemiology collaboration; CSS, cancer-specific survival; EBL, estimated blood loss; eGFR, estimated glomerular filtration rate; IQR, interquartile range; IR, intervention radiologist; NCSS, non-cancer specific survival; OS, overall survival; PN, partial nephrectomy; PVD, peripheral vascular disease; RCC, renal cell carcinoma; RMB, renal mass biopsy; RN, radical nephrectomy; TA, thermal ablation.

Regarding the most recent American Urological Association (AUA) guideline for localized RCC, surgical excision is recommended over thermal ablation (TA), and partial nephrectomy (PN) should be prioritized over radical nephrectomy (RN) if possible and without compromising oncological outcomes [5]. However, elderly patients have decreased surgical tolerance, and PN has been reported to have greater perioperative complications compared to RN and TA [7–9]. A previous study from the British Association of Urological Surgeons Nephrectomy demonstrated that all and major postoperative complications were significantly greater among older patients, and increased age was an independent factor associated with postoperative complications [8]. Meta-analysis from Pierorazio et al. [7] reported similar complication rates among patients undergoing RN, PN, and TA. However, urological complications were found to be greater among PN patients while RN patients had a higher risk of acute kidney injury. Additionally, cancer-specific survival (CSS) was comparable among all treatment modalities [7]. Shared decision-making has a substantial role between urologists and patients, weighing the risks and benefits of each treatment modality to make informed decisions [5].

The objective of this study is to evaluate the perioperative outcomes and complications among localized RCC patients aged ≥ 75 years who underwent intervention (PN, RN, or TA) and compare RCC and non-RCC-specific survival outcomes.

2 | Materials and Methods

A total of 1017 patients aged ≥ 75 years diagnosed with renal masses were identified from the Northwestern Medical Group Electronic Data Warehouse between 2000 and 2023. All patients with RCC histology were retrospectively reviewed ($n = 563$), and only 278 patients with Stage I and II kidney cancer, according to the AJCC Cancer Staging, were included. Patient demographics/comorbidities, and tumor characteristics were collected. Preoperative and postoperative estimated glomerular filtration rates (eGFRs) were calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [10]. Nephrometry score of renal masses was calculated in patients with available preprocedural images based on R.E.N.A.L. nephrometry [11].

The final decision on renal mass management was based on shared decision-making between patients and urologists after discussing the risks/benefits of each treatment modality. The choice of surgical approach (open/laparoscopic/robotic-assisted) depended on the surgeon's preferences. Referrals were made to intervention radiologists (IRs) when percutaneous TA was considered the appropriate treatment, except for 10 patients who underwent laparoscopic cryoablation. Perioperative data and the history of renal mass biopsy (RMB) were recorded. RMB was performed by IRs before or during the treatment procedures. Patients who underwent laparoscopic cryoablation had tissue diagnosis intraoperatively. Postoperative 30-day complications were classified based on the Clavien–Dindo classification, and Clavien grade ≥ 3 was considered major complication [12]. Patients were surveyed postoperatively based on cancer stage. Cross-sectional images were obtained 6 months postoperatively and then every 6–12 months regarding findings. RCC (CSS) and non-RCC-specific (NCSS: non-cancer specific survival) survival were defined from the procedure date to the last follow-up or death.

2.1 | Statistical Analysis

Continuous variables were shown as median and interquartile range (IQR), and Mann–Whitney *U* and Kruskal–Wallis tests were performed to compare between cohorts. Categorical variables were shown in numbers and percentages, and Chi-square tests were performed to compare between cohorts. Logistic regression was performed to assess the predictors of major complications, and variables with p-value ≤ 0.3 in univariable analysis were further analyzed in multivariable regression. Kaplan-Meier estimate demonstrated survival graphs, and log-rank test was performed to compare survival outcomes. All statistical significance was considered at p-value < 0.05 (two-tailed). The analyses were performed with Stata version-18 (TX; StataCorp LLC).

3 | Results

3.1 | Patient Cohorts and Baseline Characteristics

A total of 278 patients aged ≥ 75 years with Stage I or II RCC were retrospectively reviewed. Median age was 78 years, and 58% were male (Table 1). The majority of patients were Caucasian (77%), and 9% were African American. Median body mass index (BMI) was 26.6 kg/m^2. Most patients had hypertension (90%), dyslipidemia (73%), and other malignancies (85%). Almost half of patients had chronic kidney disease (CKD), and 46% had coronary artery disease (CAD). There were 42%, 35%, and 37% of patients with peripheral vascular disease (PVD), diabetes, and cerebrovascular disease, respectively. Preoperative and postoperative eGFR were 61 and 48 mL/min/1.73 m^2, respectively. Median tumor size was 3.3 cm, and 93% of patients had Stage I RCC. Median R.E.N.A.L. was 8 with 35%, 47%, and 19% of patients having low, intermediate, and high tumor complexity, respectively. Sixty-three percent of patients had clear-cell RCC, and 36% underwent RMB. The rates of RMB increased over time: 9.4% in 2000–2008, 8.3% in 2009–2013, 15.8% in 2004–2018, and 19.4% in 2019–2023.

There were 107, 101, and 70 underwent RN, PN, and TA, respectively (Table 1). The patients who underwent PN were significantly younger compared to RN and TA patients (77 vs. 79 years, $p < 0.006$). There was no difference in BMI and comorbidities among these cohorts, except TA patients had the highest proportion of other malignancies (93%, 88%, and 76% for TA, PN, and RN, respectively; $p = 0.005$). Preoperative eGFR was not significantly different among treatment modalities; however, patients who underwent RN had the lowest postoperative eGFR ($p < 0.001$). Median size of tumors was smallest in the TA cohort (2.6 cm) compared to PN (3.0 cm) and RN (4.0 cm) cohorts. Eighty-nine (83%) and 99 (98%) patients in RN and PN cohorts had Stage I kidney cancer, respectively. All patients in TA cohort had Stage I kidney cancer (89% pT1a and 11% pT1b). The median R.E.N.A.L. was greatest in RN cohort

TABLE 1 | Patient demographics and tumor characteristics.

	All patients ($n = 278$)	RN ($n = 107$)	PN ($n = 101$)	TA ($n = 70$)	p-value
Age (years), median (IQR)	78 (76–81)	79 (77–82)	77 (76–80)	79 (76–82)	***0.006***
Male, n (%)	160 (57.6)	49 (45.8)	68 (67.3)	43 (61.4)	***0.005***
Race, n (%)					0.84
Caucasian	213 (76.6)	79 (73.8)	78 (77.2)	56 (80.0)	
African American	24 (8.6)	11 (10.3)	9 (8.9)	4 (5.7)	
Others	41 (14.8)	17 (15.9)	14 (13.9)	10 (14.3)	
BMI (kg/m^2), median (IQR)	26.6 (24.2–30.7)	26.6 (23.8–29.9)	26.5 (24.3–29.9)	28.4 (24.7–32.2)	0.22
Coronary artery disease, n (%)	126 (45.7)	44 (41.9)	50 (49.5)	32 (45.7)	0.55
Pulmonary disease, n (%)	110 (39.9)	35 (33.3)	47 (46.5)	28 (40.0)	0.15
Liver disease, n (%)	77 (27.9)	25 (23.8)	32 (31.7)	20 (28.6)	0.45
Peripheral vascular disease, n (%)	115 (41.7)	41 (39.1)	48 (47.5)	26 (37.1)	0.32
Hypertension, n (%)	249 (90.2)	95 (90.5)	91 (90.1)	63 (90.0)	0.99
Dyslipidemia, n (%)	202 (73.2)	69 (65.7)	81 (80.2)	52 (74.3)	0.06
Diabetes, n (%)	96 (34.8)	32 (30.5)	35 (34.7)	29 (41.4)	0.33
Chronic kidney disease, n (%)	137 (49.6)	54 (51.4)	47 (46.5)	36 (51.4)	0.74
Cerebrovascular disease, n (%)	102 (37.0)	34 (32.4)	42 (41.6)	26 (37.1)	0.39
Other malignancies, n (%)	234 (84.8)	80 (76.2)	89 (88.1)	65 (92.9)	***0.005***
Preoperative eGFR, median (IQR)	61 (49–72)	62 (51–72)	61 (49–70)	62 (41–74)	0.57
Postoperative eGFR, median (IQR)	48 (37–66)	42 (33–48)	57 (46–72)	60 (40–78)	***< 0.001***
Tumor size (cm), median (IQR)	3.3 (2.3–4.3)	4.0 (3.1–6.2)	3.0 (2.1–3.8)	2.6 (2.0–3.2)	***< 0.001***
Right kidney, n (%)	146 (52.5)	58 (54.2)	56 (55.5)	32 (45.7)	0.41
Stage, n (%)					***< 0.001***
Stage 1	258 (92.8)	89 (83.2)	99 (98.0)	70 (100)	
Stage 2	20 (7.2)	18 (16.8)	2 (2.0)	0 (0)	
Pathological T stage, n (%)					***< 0.001***
pT1a	196 (70.5)	54 (50.5)	80 (79.2)	62 (88.6)	
pT1b	62 (22.3)	35 (32.7)	19 (18.8)	8 (11.4)	
pT2a	12 (4.3)	10 (9.3)	2 (2)	0 (0)	
pT2b	8 (2.9)	8 (7.5)	0 (0)	0 (0)	
R.E.N.A.L. score, median (IQR)	8 (6–9)	9 (8–10)	7 (6–8)	7 (6–9)	***< 0.001***
Tumor complexity, n (%)					***< 0.001***
Low	49 (34.5)	4 (9.8)	24 (48.0)	21 (41.2)	
Intermediate	66 (46.5)	21 (51.2)	23 (46.0)	22 (43.1)	
High	27 (19.0)	16 (39.0)	3 (6.0)	8 (15.7)	
Renal cell carcinoma, n (%)					0.29
Clear cell	173 (62.2)	72 (67.3)	55 (54.5)	46 (65.7)	
Papillary	75 (27.0)	22 (20.1)	35 (34.7)	18 (25.7)	
Chromophobe	20 (7.2)	10 (9.4)	6 (5.9)	4 (5.7)	
Others	10 (3.6)	3 (2.8)	5 (4.9)	2 (2.9)	
Preoperative/perioperative biopsy, n (%)	99 (35.6)	19 (17.8)	10 (9.9)	70 (100)	***< 0.001***
Operative time (minutes), median (IQR)	195 (149–247)	175 (136–215)	228 (183–282)	143 (101–197)*	***< 0.001***

(Continues)

TABLE 1 | (Continued)

	All patients ($n = 278$)	RN ($n = 107$)	PN ($n = 101$)	TA ($n = 70$)	p-value
Estimated blood loss (mL), median (IQR)	100 (50–200)	75 (50–150)	150 (60–250)	17.5 (5–50)*	***< 0.001***
Length of hospital stay (days), median (IQR)	3 (2–5)	3 (2–5)	3 (2–5)	2 (1–3)*	0.31
30-day complication, n (%)	46 (16.6)	18 (16.8)	23 (22.8)	5 (7.1)	***0.026***
Major complication, n (%)	22 (7.9)	10 (9.4)	10 (9.9)	2 (2.9)	0.19
Median follow-up (months)	48.7	49.2	67.0	31.8	
10-year renal cancer specific survival (%)	96.7	91.4	98.9	100.0	0.62
10-year non-renal cancer specific survival (%)	66.8	54.7	79.2	52.5	0.08

Note: Bold and italic values are statistically significant.
Abbreviations: BMI, body mass index; eGFR, estimated glomerular filtration rate; IQR, interquartile range; PN, partial nephrectomy; RN, radical nephrectomy; TA, thermal ablation.
*Data were obtained from laparoscopic cryoablation ($n = 10$).

(9 vs. 7; $p < 0.001$). There was no difference in RCC subtype distribution among cohorts. All TA patients underwent RMB while 18% and 10% of RN and PN had preoperative RMB ($p < 0.001$). The rate of RN has been stable since 2014 (Supporting Information: Figure 1). The PN rate increased during the 2014–2018 period when robotic PN was extensively performed (34%–51%). However, the use of TA has been increasing between 2019 and 2023 compared to 2014 and 2018 (16%–42%). Of 70 TA patients, 59 patients (84.3%) underwent cryoablation, and 10 had a laparoscopic approach. Radiofrequency and microwave ablations were performed in 3 (4.3%) and 8 (11.4%) patients, respectively.

3.2 | Radical Versus PN

There were 107 and 101 patients in RN and PN cohorts, respectively. Patients who underwent PN were significantly younger than those who had RN (77 vs. 79 years; $p = 0.002$, Supporting Information: Table 1). BMI was not significantly different between cohorts. The percentages of dyslipidemia and other malignancies were significantly greater in PN cohort ($p \leq 0.03$). There was no significant difference in preoperative eGFR between the two groups; however, patients who underwent RN had a significantly lower postoperative eGFR (42 vs. 57; $p < 0.001$). Median tumor size was smaller in the PN group (3 vs. 4 cm; $p < 0.001$), and tumors in RN cohort also had greater complexity (R.E.N.A.L. 9 vs. 7; $p < 0.001$). Most patients in RN group had laparoscopic approach (70%), while robotic surgery was mostly performed in PN group (65%). RN cohort had a higher proportion of Stage II kidney cancer compared to PN cohort (17% vs. 2%; $p < 0.001$). Operative time and estimated blood loss (EBL) were reported to be significantly greater in PN group; however, length of hospital stay was not different.

3.3 | Nephrectomy Versus TA

The 208 patients receiving nephrectomy (RN or PN) were compared to the 70 TA patients. There was no age difference between cohorts (Supporting Information: Table 2). Comorbidities between cohorts were not different, except TA cohort had greater percentage of other malignancies (93% vs. 82%; $p = 0.03$). Postoperative eGFR was significantly better in TA patients compared to the nephrectomy group (60 vs. 47; $p = 0.004$). All TA patients had stage I kidney cancer and smaller tumor sizes (2.6 vs. 3.5 cm; $p < 0.001$). There was no difference in tumor complexity between groups. When compared to laparoscopic cryoablation ($N = 10$), patients who underwent nephrectomy had significantly longer operative time and EBL.

3.4 | Perioperative and Postoperative Complications

There were 46 postoperative complications (16.6%): 18 (16.8%) in RN, 23 (22.8%) in PN, and 5 (7.1%) in TA cohorts (Table 1). The complication rate was significantly greater in PN patients ($p = 0.026$). Nonetheless, there was no difference in major complications ($p = 0.19$): 22 (7.9%) overall, 10 (9.4%) in RN, 10 (9.9%) in PN, and 2 (2.9%) in TA cohorts. There were six urological complications. One RN patient had postoperative oliguria and underwent contralateral ureteral stent insertion. Five PN patients experienced urine leakage. Two patients had ureteral stents, and the others underwent nephrostomy insertion. There were two mortalities. The first patient underwent laparoscopic conversion to open nephrectomy due to inferior vena cava injury and then developed acute renal and respiratory failure and passed away. The latter patient had massive pulmonary emboli on postoperative Day 1.

Focused on patients who underwent nephrectomy, PVD and cancer comorbidities were associated with major complications on univariate analysis (Table 2). Only PVD predicted major complications on multivariable analysis (OR 3.45; 95% confidence interval [CI] 1.09–10.7).

3.5 | Survival Outcomes

The median follow-up was 48.7 months: 49.2 in RN, 67.0 in PN, and 31.8 in TA cohorts. The 5-year CSS and NCSS estimates

TABLE 2 | Univariate and multivariate analyses for factors associated with major postoperative complications among patients underwent nephrectomy.

	Univariate analysis		Multivariate analysis	
	OR (95% CI)	*p*-value	OR (95% CI)	*p*-value
Age	0.98 (0.86–1.13)	0.79		
Male	1.19 (0.46–3.03)	0.72		
BMI	0.99 (0.99–1.00)	0.89		
Intervention				
Radical nephrectomy	Reference			
Partial nephrectomy	1.07 (0.42–2.68)	0.89		
Approach				
Open	Reference		Reference	
Robotic	0.35 (0.10–1.17)	0.09	0.49 (0.13–1.86)	0.30
Laparoscopic	0.53 (0.17–1.62)	0.26	0.71 (0.21–2.35)	0.58
Tumor complexity				
Low	Reference			
Intermediate	0.63 (0.04–10.5)	0.75		
High	3.18 (0.27–37.8)	0.36		
Coronary artery disease	1.90 (0.74–4.87)	0.18	2.02 (0.68–5.98)	0.20
Pulmonary disease	1.27 (0.50–3.21)	0.62		
Liver disease	1.13 (0.41–3.11)	0.81		
Peripheral vascular disease	3.45 (1.27–9.39)	***0.02***	3.42 (1.09–10.7)	***0.03***
Hypertension	0.96 (0.21–4.50)	0.96		
Dyslipidemia	0.86 (0.31–2.35)	0.77		
Diabetes	0.88 (0.32–2.40)	0.80		
Chronic kidney disease	1.30 (0.52–3.29)	0.58		
Cerebrovascular disease	0.91 (0.35–2.40)	0.85		
Other malignancies	0.36 (0.13–0.97)	***0.04***	0.38 (0.11–1.27)	0.12
Mass biopsy	1.10 (0.30–4.01)	0.89		

Note: Bold and italic values are statistically significant.
Abbreviations: CI, confidence interval; OR, odds ratio.

among all patients were 99.2% and 88.2%, respectively. There was no difference in CSS between 3 cohorts ($p = 0.62$; Figure 1A). The 5-year CSS rates were 99%, 98.9%, and 100% in RN, PN and TA cohorts, respectively. NCSS was not significantly different among treatment modalities ($p = 0.08$; Figure 1B). The 5-year NCSS rates were 87.9%, 89.2%, and 86.9% in RN, PN and TA cohorts, respectively. PN patients appeared to have longer NCSS by 10 years (10-year NCSS: 79.2% for PN, 54.7% for RN, and 52.5% for TA).

4 | Discussion

Localized kidney cancer has been increasingly diagnosed in the United States and globally [1–3]. Surgical extirpation is the standard treatment [4–7]. However, advanced-age patients encounter numerous competing mortality risks apart from localized kidney cancer [6, 13, 14]. A previous Agency for Healthcare Research and Quality systematic review and meta-analysis reported similar CSS and overall survival (OS) among all treatment strategies for localized RCC, although TA demonstrated higher recurrent rates [7]. Old patients with cardiovascular risks were associated with decreased OS, and surgery was beneficial only in patients with lower cardiovascular risks [13, 14]. A primary goal of treating localized RCC in elderly patients is section to extend survival while balancing complications and competing risks.

A rise in PN has been observed to benefit localized RCC patients by providing better postoperative renal function, leading to improved OS [5, 15, 16]. Our study demonstrated a consistent trend of PN over RN among elderly patients; however, the use of TA has increased as it has become a less invasive nephron-sparing option which can reduce surgical complications [6, 7, 16–18]. A prior 1:1 propensity-score matched study from Cleveland Clinic included 130 patients aged > 75 years who underwent robotic PN or percutaneous/laparoscopic cryoablation (2006–2016) and demonstrated complication rates were greater in robotic PN cohort (31% vs. 9%, $p = 0.007$) [18]. However, no significant difference in

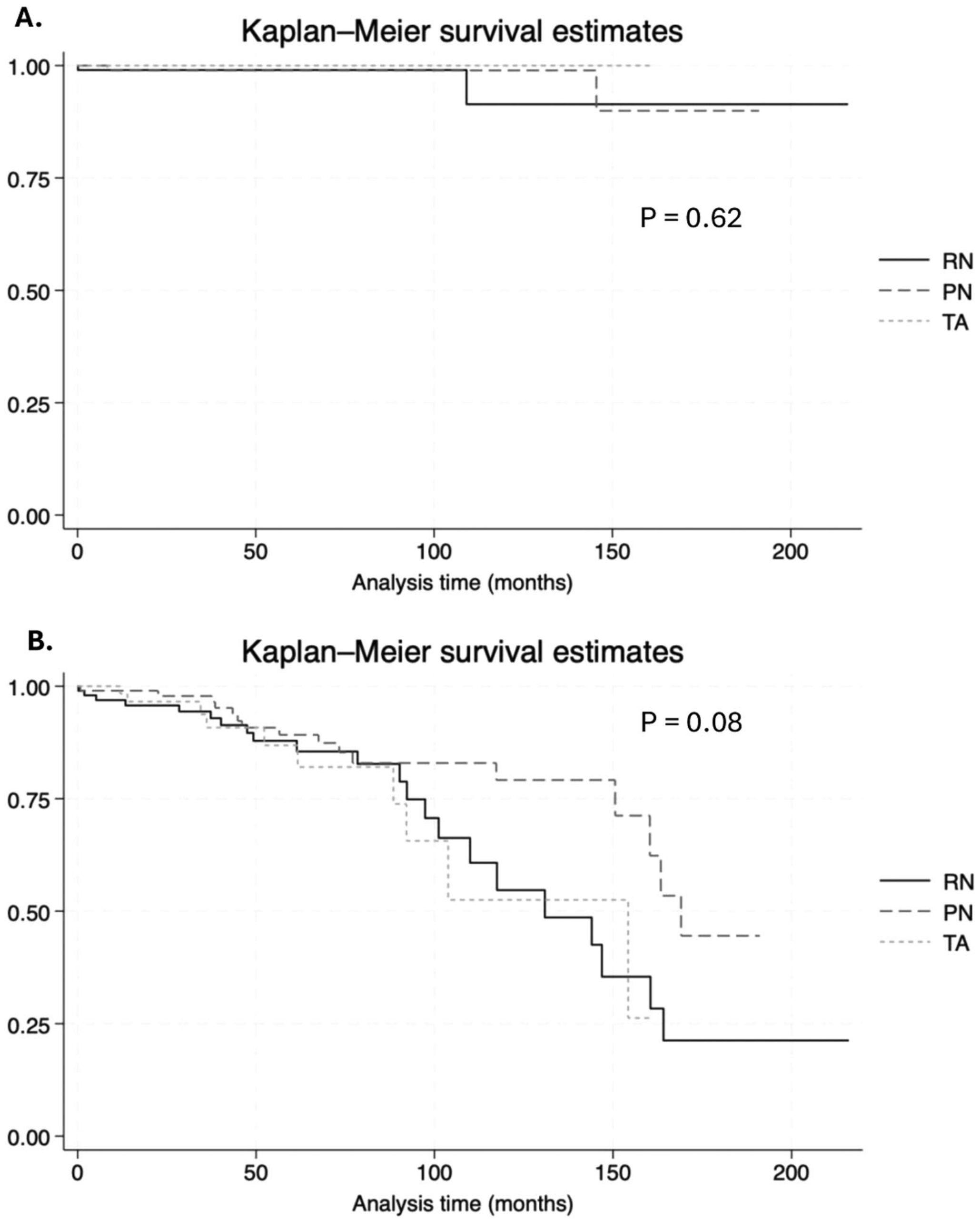

FIGURE 1 | Kaplan–Meier survival estimates between RN (radical nephrectomy), PN (partial nephrectomy), and TA (thermal ablation): (A) RCC (renal cell carcinoma)-specific survival and (B) non-RCC-specific survival. Log-rank test was performed to compare the survival outcomes.

major complications was found: 6% and 1.5% in robotic PN and cryoablation, respectively ($p = 0.2$). The cryoablation cohort had significantly shorter operative time and less EBL. Our study had similar findings. The PN cohort had a significantly greater rate of postoperative complication compared to RN and TA; however, there was no difference in major complication rates. PN had significantly longer operative time and more EBL. In another study, O'Malley et al. [19] compared complication rates between RN and PN based on age cutoff of 75 years. Patients aged ≥ 75 years had a lower possibility of undergoing PN compared to younger patients (26% vs. 43%, $p = 0.045$). Age and nephrectomy type (RN/PN) were not associated with postoperative complications. Importantly, PVD was a predictor of major postoperative complications in our study and could identify candidates more appropriate for TA if they harbored amenable tumors.

Impaired renal function is a major concern after treatment of RCC [5, 16–19]. A recent study from Kawaguchi et al. [17] compared preoperative and postoperative renal function after robotic PN and percutaneous cryoablation in RCC patients aged ≥ 70 years. There was no difference in preoperative eGFR before the procedure; however, patients in cryoablation group had a greater decrease in eGFR when compared to PN group (14 vs. 5 mL/min/1.73 m^2). The authors found that intermediate-high nephrometry score was associated with > 20% reduction in eGFR 1-year postoperatively. There was no significant difference in OS and recurrence-free survival rates between the two groups. Patients in our study had no difference in preoperative eGFR. Nevertheless, patients who underwent RN had a significant decline in eGFR compared to patients receiving PN and TA cohorts ($p < 0.001$).

Despite the potential benefits, it remains uncertain whether elderly patients can truly experience the same advantages of nephron-sparing surgery [5–7, 15–19]. Ristau et al. [15] reviewed 212,016 localized RCC patients from the National Cancer Database who underwent RN or PN (2004–2014). The OS benefit significantly favored PN over RN with the 5-year OS rate of 90% versus 85% for T1a tumors and 83% versus 81% for T1b/T2 tumors ($p \leq 0.01$). However, such benefits were not found in patients ≥ 75 years. We found no CSS and NCSS differences between all treatment modalities in our study.

The role of RMB has been increasing and recommended to be considered where it may impact clinical decision-making [5, 16, 20–23]. The diagnostic and accuracy rates of core biopsy are acceptable (95%–99% sensitivity, 94%–100% specificity, and 99% positive predictive value), and its significant complication rate is low (1%–8%) from recent literature [5, 16, 20, 23–25]. Previous studies showed that 20%–30% of suspicious kidney cancers had benign pathology on RMB and could avoid surgical interventions [21, 23, 26–28]. The negative predictive value of RMB can also be improved using immunohistochemistry and radiomics [29]. The RMB rate before nephrectomy in our study was low—17.8% and 9.9% for RN and PN, respectively; however, the rates have been increasing over time (9.4%–19.4%). RMB is also strongly recommended before TA [5]. A recent study from the Kidney Tumor Program in North Carolina retrospectively reviewed patients with small renal masses (2000–2020) and found a significant increase in RMB after the AUA recommendation [21]. Of all treatment modalities, the RMB rate increased from 7.6% to 19% ($p < 0.001$) and significantly increased among TA patients (22%–94%). Changes in treatment decisions were substantial in surgery (46%–22%, $p < 0.001$) and active surveillance (15%–43%, $p < 0.001$) cohorts. Invasive procedures with potential complications could be avoided based on RMB results [16, 22].

Our study is listed by its retrospective nature and selection bias for interventions. However, we aimed to provide a representative real-world evaluation on use of RN, PN, and TA among older patients at our institution. We also focused on and included only patients with confirmed RCC given evaluation of CSS and NCSS. Due to the limited number of TA patients receiving different energy modalities, TA type was not incorporated into the analysis. Finally, our study had a moderate follow-up, but an extended duration may be necessary to evaluate long-term NCSS.

5 | Conclusions

An increasing number of advanced-age patients have been diagnosed with localized kidney cancer. Comorbidities have a substantial impact on patients' survival and complications from cancer treatments. Making an informed decision about a treatment requires careful consideration of both its potential benefits and risks. RMB might play a significant role in such patients to avoid unnecessary treatments, and PVD could serve as a selection factor favoring TA for amenable tumors.

Author Contributions

Chalairat Suk-ouichai: conceptualization, data curation, formal analysis, project administration, and writing–original draft preparation. **Hiten D. Patel**, **Kent T. Sato**, **Shilajit D. Kundu**, and **Ashley E. Ross:** methodology, resources, writing–review and editing, and supervision. **Kent T. Perry Jr.:** conceptualization, methodology, resources, writing–review and editing, and supervision.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data available on request from the authors.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.