EUROPEAN UROLOGY FOCUS XXX (2018) XXX–XXX

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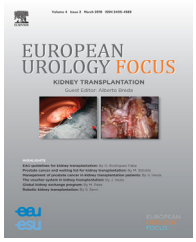

Kidney Cancer

Trifecta Outcomes of Partial Nephrectomy in Patients Over 75 Years Old: Analysis of the REnal SURGery in Elderly (RESURGE) Group

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Article info

Article history:
Accepted February 13, 2019

Associate Editor. Malte Rieken

Abstract

Background: Partial nephrectomy (PN) in elderly patients is underutilized with concerns regarding risk of complications and potential for poor outcomes.
Objective: To evaluate quality and functional outcomes of PN in patients >75 yr using trifecta as a composite outcome of surgical quality.
Design, setting, and participants: Multicenter retrospective analysis of 653 patients aged >75 yr who underwent PN (REnal SURGery in Elderly [RESURGE] Group).
Intervention: PN.
Outcome measurements and statistical analysis: Primary outcome was achievement of trifecta (negative margin, no major [Clavien ≥3] urological complications, and ≥90% estimated glomerular filtration rate [eGFR] recovery). Secondary outcomes included chronic kidney disease (CKD) stage III and CKD upstaging. Multivariable analysis (MVA) was used to assess variables for achieving trifecta and functional outcomes. Kaplan-Meier survival analysis (KMA) was used to calculate renal functional outcomes.
Results and limitations: We analyzed 653 patients (mean age 78.4 yr, median follow-up 33 mo; 382 open, 157 laparoscopic, and 114 robotic). Trifecta rate was 40.4% (n = 264).

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https://doi.org/10.1016/j.euf.2019.02.010
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Please cite this article in press as: Bindayi A, et al. Trifecta Outcomes of Partial Nephrectomy in Patients Over 75 Years Old: Analysis of the REnal SURGery in Elderly (RESURGE) Group. Eur Urol Focus (2019), https://doi.org/10.1016/j.euf.2019.02.010

Keywords:
Carcinoma
Chronic Kidney Disease
Elderly
Outcome Assessment
Partial Nephrectomy
Renal Cell
Trifecta

Trifecta patients had less transfusion ($p < 0.001$), lower intraoperative (5.3% vs 27%, $p < 0.001$) and postoperative (25.4% vs 37.8%, $p = 0.001$) complications, shorter hospital stay ($p = 0.045$), and lower ΔeGFR ($p < 0.001$). MVA for predictive factors for trifecta revealed decreasing RENAL nephrometry score (odds ratio [OR] 1.26, 95% confidence interval 1.07–1.51, $p = 0.007$) as being associated with increased likelihood to achieve trifecta. Achievement of trifecta was associated with decreased risk of CKD upstaging (OR 0.47, 95% confidence interval 0.32–0.62, $p < 0.001$). KMA showed that trifecta patients had improved 5-yr freedom from CKD stage 3 (93.5% vs 57.7%, $p < 0.001$) and CKD upstaging (84.3% vs 8.2%, $p < 0.001$). Limitations include retrospective design.
Conclusions: PN in elderly patients can be performed with acceptable quality outcomes. Trifecta was associated with decreased tumor complexity and improved functional preservation.
Patient summary: We looked at quality outcomes after partial nephrectomy in elderly patients. Acceptable quality outcomes were achieved, measured by a composite outcome called trifecta, whose achievement was associated with improved kidney functional preservation.
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1. Introduction

Renal cell carcinoma (RCC) is the 17th most common cancer worldwide with approximately 403 262 new diagnoses and 175 098 deaths reported in 2018. Incidence rates have increased, with largest increases among elderly patients (age ≥75 yr) [1,2]. While active surveillance (AS) is an appropriate management strategy in tumors <2 cm in size, especially in patients who may have a limited life expectancy [3], data suggest that age may represent an independent risk factor for cancer-specific mortality in subgroups of RCC patients [4]. Partial nephrectomy (PN) has emerged as the reference standard for management of cT1 renal masses with oncological equivalence to radical nephrectomy (RN) and benefits of functional preservation [3,5]. Nonetheless, while utilization of PN has increased overall [6], it continues to be underutilized in elderly patients even when indicated [6,7]. The causes of PN underutilization in elderly patients are likely multifactorial, though a prevailing concern regarding potential impact of risks of procedure-specific complications in the setting of worsened baseline preexisting medical comorbidities continues. In recent years, development of composite measures of surgical quality (trifecta) have aimed to provide a standardized basis for analysis of outcomes [8]. We hypothesized that PN in elderly patients had acceptable quality outcomes as reflected by trifecta, and that trifecta was driven by tumor complexity and in turn impacted functional outcomes and utilized a multi-institutional international data set of elderly patients undergoing PN to answer our questions.

2. Patients and methods

2.1. Patient population

Retrospective analysis of a multi-institutional data set of 653 patients who underwent to PN for a renal mass between 2000 and 2016 at 19 institutions participating in the REnal SURGery in Elderly (RESURGE) Group. Patients >75 yr of age were defined as "elderly" in accordance with major guidelines [5,9]. Elderly patients who underwent PN for a clinically localized renal tumor were included. Operations were performed by urologic oncologists. Patients undergoing PN in the setting of locally advanced and metastatic disease, urothelial tumors or inflammatory lesions, and without sufficient follow-up (< 6 mo) were excluded ($n = 209$). Institutional Review Board approval was obtained at each center.

2.2. Covariates and outcomes

Demographic data included age, sex, body mass index (kg/m^2), comorbidities (diabetes mellitus and hypertension), American Society of Anesthesiologists score, Charlson Comorbidity Index score, TNM stage [10], RENAL nephrometry [11], surgical approach, operative information (operative time, transfusion, estimated blood loss [EBL], type of ischemia, warm ischemia time [WIT]), length of stay (LoS), and renal function (estimated glomerular filtration rate [eGFR], calculated by Chronic Kidney Disease Epidemiology Collaboration [CKD-EPI]) [12]. Complications and readmission rates were reported as intraoperative, postoperative, major urological, and 30-d readmission rates. Major urological complications were reported using the Clavien-Shabsigh system (Clavien grade ≥3) [13]. RENAL score was categorized into low (4–6), intermediate (7–9), and high (10–12) [11]. Final pathological variables included pathological stage, histologic subtype of RCC, nuclear grade, and positive surgical margin rate. Trifecta was categorized as negative surgical margin, no major urological complications, and ≥90% eGFR recovery 6 mo postoperative as defined by Hung et al [14].

2.3. Statistical analysis

The Cochran-Armitage test for trend was used to quantify changes in use of different surgical approaches over the study period. Primary outcome was trifecta rate. After calculation of trifecta, the cohort was subdivided into patients who achieved (trifecta positive) and those who did not (trifecta negative). Descriptive analyses were conducted for the overall cohort and for comparisons. Continuous variables were analyzed using the independent *t* test and analysis of variance and categorical variables were analyzed using Fisher's exact and chi-square tests.

Univariable and multivariable (MVA) regression models were used to detect predictors for major urologic complications, positive trifecta, and chronic kidney disease (CKD) upstaging. Using the logistic regression method, variables were analyzed in a univariable model and utilizing purposeful selection of relevant variables with $p \leq 0.25$ entered into the final multivariable model. Kaplan-Meier survival analyses (KMA) were obtained for freedom from de novo CKD stage III (eGFR <60 ml/min/1.73 m^2) at last follow-up and CKD upstaging postsurgery of trifecta positive vs negative groups. Statistical analyses were performed using the SPSS version 21.0 (IBM, Chicago, IL, USA), with $p < 0.05$ considered significant.

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Table 1 – Baseline demographics and outcomes stratified by trifecta achievement.

	Overall cohort (n = 653)	Positive trifecta (n = 264)	Negative trifecta (n = 389)	p value
Median (IQR) follow-up (mo)	33.1 (27–41)	34.7 (28–42)	32.1 (26–40)	0.094
Age (yr), mean ± SD	78.4 ± 3.2	78.3 ± 3.1	78.5 ± 3.2	0.355
Sex, male, n (%)	365 (55.9)	154 (58.3)	211 (54.2)	0.335
Body mass index, mean ± SD	25.8 ± 3.9	26.1 ± 4.3	25.7 ± 3.7	0.269
Diabetes mellitus (positive), n (%)	175 (26.7)	68 (25.7)	107 (27.6)	0.646
Hypertension (positive), n (%)	413 (63.2)	169 (64.1)	244 (62.7)	0.735
Solitary kidney, n (%)	45 (6.9)	12 (4.5)	33 (8.7)	0.307
Preoperative CKD stage ≥III, n (%)	275 (42.1)	129 (48.9)	146 (37.5)	0.005
American Society of Anesthesiologists score, mean ± SD	2.3 ± 0.6	2.3 ± 0.6	2.3 ± 0.6	0.294
Charlson Comorbidity Index score, mean ± SD	3.4 ± 0.5	3.4 ± 0.4	3.5 ± 0.5	0.187
RENAL score, mean ± SD	6.8 ± 1.9	6.5 ± 1.9	6.9 ± 1.9	0.008
Clinical tumor size (cm), mean ± SD	3.5 ± 2.9	3.3 ± 2.5	3.6 ± 2.1	0.024
Clinical T stage, n (%)				0.548
T1a	501 (76.7)	209 (79.2)	292 (75)	
T1b	121 (18.5)	42 (15.9)	79 (20.4)	
T2a	29 (4.4)	12 (4.5)	17 (4.4)	
T2b	2 (0.3)	1 (0.4)	1 (0.3)	
Surgical approach				0.489
Open	325	124 (38.2)	201 (61.8)	
Laparoscopic	176	76 (43.2)	100 (56.8)	
Robotic	152	64 (42.1)	88 (57.9)	
Ischemia time, mean ± SD	23.1	21.9	23.9	0.109
Intraoperative transfusion, n (%)	57 (8.7)	13 (4.9)	44 (11.3)	0.005
Intraoperative complications, n (%)	44 (6.7)	9 (3.4)	35 (9.0)	0.020
Postoperative complications, n (%)	105 (16.1)	27 (10.2)	78 (20.1)	0.001
Length of stay, mean ± SD	6.7 ± 3.7	6.1 ± 4.1	7.2 ± 4.5	0.045
30-d readmission rate, n (%)	19 (2.9)	8 (3.1)	11 (2.8)	0.925
Positive surgical margin, n (%)	24 (3.7)	0 (0)	24 (6.2)	<0.001
Estimated blood loss (ml), mean ± SD	263.7 ± 196.6	203.2 ± 121.2	303.9 ± 176.1	0.089
Tumor pathology type, n (%)				0.317
Clear cell RCC	478 (73.2)	195 (73.8)	283 (72.8)	
Papillary RCC	54 (8.2)	18 (6.8)	36 (9.3)	
Chromophobe RCC	29 (4.5)	10 (3.7)	19 (4.9)	
Other subtype of RCC	10 (1.4)	6 (2.2)	4 (1.1)	
Oncocytoma	59 (9)	24 (9)	35 (9)	
Angiomyolipoma	10 (1.5)	4 (1.5)	6 (1.5)	
Other benign	13 (1.9)	7 (2.6)	6 (1.4)	
Preoperative eGFR, mean ± SD	61.5 ± 11.2	61.2 ± 10.3	61.7 ± 12.6	0.194
Postoperative eGFR, mean ± SD	58.1 ± 13.2	63.5 ± 12.2	54.0 ± 10.9	<0.001
ΔeGFR mean ± SD	−3.4 ± 11.3	2.3 ± 10.3	−7.7 ± 12.9	<0.001
De novo CKD stage III, n (%)	186 (28.5)	6 (2.3)	180 (46.3)	<0.001
CKD upstaging, n (%)	242 (37)	12 (4.5)	230 (59.1)	<0.001
+1	182 (27.9)	12 (4.5)	170 (43.7)	
≥ +2	60 (9.1)	0	60 (15.4)	
Follow-up (mo), mean ± SD	38.1 ± 30.5	37.7 ± 29.8	38.4 ± 30.9	0.766

CKD = chronic kidney disease; eGFR = estimated glomerular filtration rate; IQR = interquartile range; RCC = renal cell carcinoma; SD = standard deviation.

3. Results

Mean age and the median follow-up time of the cohort were 78.4 yr and 38.1 mo, respectively; 55.9% (n = 365) were male and 44.1% (n = 288) female. Imperative indications for PN (renal insufficiency, solitary kidney, or bilateral synchronous tumors) were present in 43.8% (n = 286). Of the cohort, 49.8% (325) underwent open, 27% (176) laparoscopic, and 23.2% (152) robotic surgery. Trifecta was achieved by 40.4% (264 patients), with overall negative margin rate of 96.3% (629 patients), no major urologic complications in 94.0% (614 patients), and ≥90% return to baseline eGFR in 45.8% (299 patients).

Table 1 presents baseline demographics, clinical characteristics, and outcomes of the entire cohort and trifecta positive and trifecta negative groups. Compared with patients who did not achieve trifecta (389), patients with trifecta had lower RENAL score (6.5 vs 6.9, p = 0.008) and smaller tumor size (3.3 vs 3.6 cm, p = 0.024). No significant differences were noted between the groups with respect to surgical approach (p = 0.489) and mean ischemia time (-p = 0.109). Patients with trifecta had lower intraoperative transfusion (4.9% vs 11.3%, p = 0.005), intraoperative (3.4% vs 9%, p = 0.02) and postoperative (10.2% vs 20.1%, p = 0.001) complications, and shorter hospital stay (p = 0.045). Functionally, trifecta patients had smaller ΔeGFR (+2.3 vs −7.7 ml/min/1.73 m^2, $p < 0.001$) and lower de novo CKD stage III (2.3% vs 46.3%, $p < 0.001$) and CKD upstaging (4.5% vs 59.1%, $p < 0.001$).

Figure 1 demonstrates temporal trends in utilization of different surgical platforms over the study period. There was a decline in utilization of open surgery from 90% of PN

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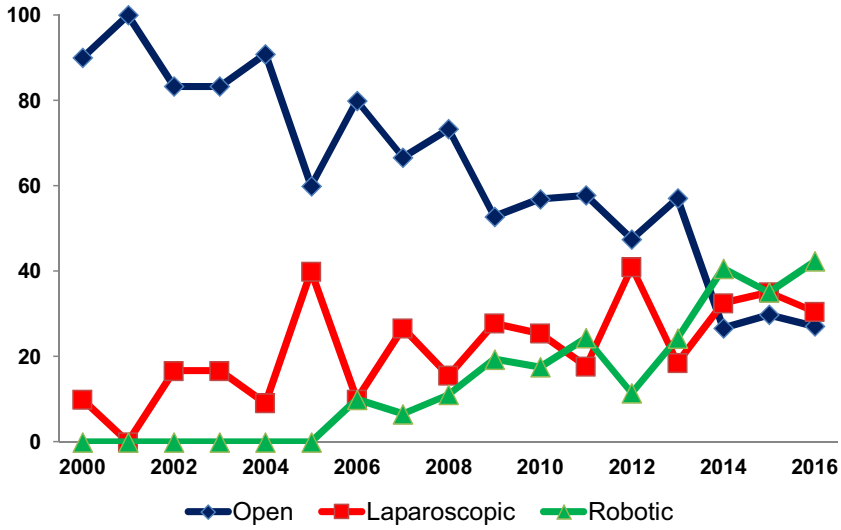

Fig. 1 – Utilization of open, laparoscopic, and robotic partial nephrectomy over the study period (Cochran-Armitage test for trend; $p < 0.001$ for all groups).

in 2000 to 27.1% in 2016 ($p < 0.001$). There were corresponding increases in proportions of laparoscopic (10% in 2001 to 30.5% in 2016, with a peak of 41% in 2012, $p < 0.001$) and robotic PN (starting utilization in 2006 and becoming the most common platform in 2016 with 42.4%, $p < 0.001$).

Table 2 presents clinical characteristics, and operative, surgical, and functional outcomes according to surgery type. Mean RENAL score ($p = 0.003$), EBL ($p < 0.001$), and LoS ($p = 0.001$) were higher in open surgery compared with laparoscopic and robotic surgery. The highest mean ischemia time was in laparoscopic (25.4 min) surgery when compared with open (23.1 min) and robotic (19.3 min) surgeries ($p < 0.001$). No significant differences were seen between groups with respect to intraoperative (open 5.8% vs laparoscopic 9.7% vs robotic 5.3%, $p = 0.189$) or postoperative ($p = 0.15$) complications. No differences were noted between groups with respect to margins ($p = 0.470$), functional recovery ($p = 0.953$), and trifecta achievement (open 38.5%, laparoscopic 42.6%, and robotic 42.1%, $p = 0.591$).

Table 3 presents univariable analysis and MVA for factors associated with major urologic complications. MVA revealed increasing RENAL score (odds ratio [OR] 1.23, $p = 0.043$) as an independent risk factor while surgical approach ($p = 0.183–0.761$) was not (Table 3). MVA for predictive factors for trifecta revealed decreasing RENAL score (OR 1.26, $p = 0.007$) and EBL (OR 1.03, $p = 0.025$) as being independently associated with trifecta achievement (Table 4). MVA for postoperative CKD upstaging revealed that ischemia time >30 min (OR 2.76, $p = 0.048$) and receipt of intraoperative transfusion (OR 2.7, $p = 0.043$) as being predictive factors for CKD upstaging postoperatively, whereas achievement of trifecta was associated with decreased risk (OR 0.47, $p < 0.001$; Table 5).

Figure 2 demonstrates KMA for freedom from de novo CKD stage 3 and CKD upstaging. Five-year probability of freedom from new onset of CKD stage III was 93.5% for trifecta-positive and 57.7% for trifecta-negative patients (-$p < 0.001$; Fig. 2A). Similarly, 5-yr freedom from CKD upstaging was 84.3% in trifecta-positive patients and 8.2% in trifecta-negative patients ($p < 0.001$; Fig. 2B).

4. Discussion

We report the largest analysis of PN quality outcomes in elderly patients. We found that nephron-sparing surgery can offer acceptable quality outcomes and ultimately maximize functional preservation. As such, if feasible and indicated based on an individualized assessment of competing mortality and risks, PN is appropriate and should be attempted. Tumor complexity plays a significant role as a driver of major urologic complications and trifecta achievement. Furthermore, a composite marker of surgical quality (trifecta) correlates with functional outcomes. Finally, utilization of the robotic platform is associated with benefits in recovery and blood loss while not compromising quality outcomes.

Current guidelines recommend PN as the primary treatment method for small renal masses [4,5]. Nonetheless, evidence exists that even in the setting of imperative indications PN remains underutilized [6,7]. This disparity in quality of care is even more evident in the elderly population, where utilization of PN has lagged and where patients may be at even higher risk for renal insufficiency. In our cohort, 43.7% of patients had imperative indication for PN, which is reflective of the higher risk status of this group when compared with other contemporary RCC series, which demonstrate that approximately 26% of patients presenting with renal mass have pre-existing CKD [15]. While use of PN for surgical treatment of small renal masses in elderly patients has grown, it has lagged behind that of other age groups. Using Surveillance Epidemiology and End Results Medicare data, Tan et al [16] reported 26.8% increase in use of PN from 2000 to 2009 in patients aged >65 with stage I RCC. Nonetheless, when compared with patients aged 65–69 yr, those aged 75–79 yr (OR 0.80, $p = 0.005$), 80–84 yr (OR 0.55, $p < 0.001$), and ≥85 yr (OR 0.76, $p < 0.001$) were less

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Table 2 – Baseline demographics and outcomes of the cohort according to surgery type.

	Open (n = 325)	Laparoscopic (n = 176)	Robotic (n = 152)	p value
Age (yr), mean ± SD	78.4 ± 3.2	77.7 ± 2.6	79.4 ± 3.4	<0.001
Sex, male, n (%)	182 (56)	102 (58.0)	81 (53.2)	0.698
Body mass index, mean ± SD	25.6 ± 4.3	26.1 ± 3.1	26.1 ± 4	0.437
Diabetes mellitus (positive), n (%)	81 (24.9)	47 (26.7)	467 (30.9)	0.387
Hypertension (positive), n (%)	204 (62.8)	117 (66.5)	92 (60.5)	0.879
Solitary kidney, n (%)	34 (10.5)	5 (2.8)	6 (3.9)	0.001
Preoperative CKD stage ≥III, n (%)	148 (45.6)	53 (30.1)	74 (48.7)	0.001
American Society of Anesthesiologists score, mean ± SD	2.4 ± 0.6	2.3 ± 0.5	2.1 ± 0.6	0.016
Charlson Comorbidity Index score, mean ± SD	3.5 ± 0.3	3.5 ± 0.4	3.4 ± 0.5	0.107
RENAL score, mean ± SD	7.1 ± 1.9	6.4 ± 1.8	6.6 ± 1.9	0.003
Ischemia time (min), mean ± SD	23.1 ± 13.1	25.4 ± 16.1	19.3 ± 7.5	<0.001
Estimated blood loss (ml), mean ± SD	351.9 ± 195.1	192.9 ± 98.4	157.6 ± 94.4	<0.001
Length of stay (d), mean ± SD	7.6 ± 4.9	6 ± 3.7	5.6 ± 3.9	0.001
30-d readmission rate, n (%)	8 (2.5)	9 (5.1)	2 (1.3)	0.099
Intraoperative complications, n (%)	19 (5.8)	17 (9.7)	8 (5.3)	0.189
Postoperative complications, n (%)	55 (16.9)	33 (18.8)	17 (11.2)	0.150
Intraoperative transfusion, n (%)	32 (9.8)	21 (11.9)	4 (2.6)	0.003
Trifecta rate	125 (38.5)	75 (42.6)	64 (42.1)	0.591
Negative margins	314 (96.6)	171 (97.1)	144 (94.7)	0.470
No major urologic complications	306 (94.2)	167 (94.9)	141 (92.8)	0.715
≥90% Estimated glomerular filtration rate recovery	139 (42.8)	87 (49.4)	73 (48)	0.953
No CKD upstaging, n (%)	204 (62.8)	108 (61.4)	99 (65.1)	0.779

CKD = chronic kidney disease; SD = standard deviation.

Table 3 – Univariable and multivariable logistic regression analysis for predictors of major urologic complications.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	p value	OR	95% CI	p value
Age (increasing)	1.08	0.66–1.21	0.193	1.02	0.88–1.20	0.760
Body mass index (increasing)	1.02	0.93–1.18	0.734			
Diabetes mellitus (positive)	1.08	0.40–2.20	0.164	1.288	0.60–2.75	0.512
American Society of Anesthesiologists score (increasing)	1.02	0.51–1.67	0.793			
Charlson Comorbidity Index score (increasing)	1.10	0.76–1.43	0.236			
Clinical tumor size (increasing)	1.01	0.99–1.03	0.119			
RENAL score (increasing)	1.17	0.97–1.41	0.072	1.23	0.98–1.55	0.043
Open surgery (reference)						
Laparoscopic surgery	1.18	0.91–1.40	0.671	1.13	0.85–1.29	0.761
Robot-assisted surgery	0.94	0.77–1.21	0.125	0.89	0.84–1.13	0.183

CI = confidence interval; OR = odds ratio.

Table 4 – Univariable and multivariable logistic regression analysis for positive trifecta achievement.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	p value	OR	95% CI	p value
Age (increasing)	0.98	0.93–1.03	0.357	0.99	0.89–1.08	0.978
Gender (male vs female)	1.18	0.86–1.62	0.302	1.08	0.60–1.95	0.902
Body mass index (increasing)	1.03	0.98–1.07	0.269	0.97	0.89–1.06	0.419
American Society of Anesthesiologists score (increasing)	0.85	0.62–1.15	0.293	0.81	0.55–1.63	0.427
RENAL score (decreasing)	1.14	1.03–1.25	0.009	1.26	1.07–1.51	0.007
Minimally invasive surgery versus open surgery	1.32	0.96–1.82	0.084	1.37	0.77–2.94	0.171
Ischemia time ≤30 vs >30 min	1.67	0.96–2.90	0.071	1.50	0.59–3.89	0.149
Estimated blood loss (decreasing)	1.04	1.01–1.08	0.096	1.03	1.01–1.06	0.025
Year of surgery (increasing)	1.01	0.99–1.03	0.311	1.02	1.00–1.04	0.311

CI = confidence interval; OR = odds ratio.

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Table 5 – Univariable and multivariable logistic regression analysis for chronic kidney disease upstaging postoperatively.

	Univariate analysis			Multivariate analysis		
	OR	95% CI	*p* value	OR	95% CI	*p* value
Age (increasing)	1.00	0.95–1.05	0.946			
Gender (male vs female)	0.80	0.57–1.11	0.177	1.28	0.63–2.60	0.499
Diabetes mellitus (positive)	1.05	0.72–1.53	0.782			
Body mass index (increasing)	0.99	0.95–1.04	0.776			
American Society of Anesthesiologists score (increasing)	1.20	0.88–1.63	0.250	1.14	0.62–2.09	0.682
Tumor size (increasing)	1.01	1.00–1.02	0.241			
RENAL score (increasing)	1.06	0.96–1.17	0.229	0.90	0.72–1.12	0.330
Minimally invasive surgery vs Open surgery	0.94	0.67–1.30	0.698			
Ischemia time (increasing)	1.03	1.01–1.05	0.001			
Ischemia time >30 vs ≤30 min	2.42	1.39–4.27	0.002	2.76	0.97–7.90	0.048
Estimated blood loss (increasing)	1.00	1.00–1.00	0.338			
Intraoperative transfusion (positive)	3.81	2.25–6.44	<0.001	2.70	1.03–7.04	0.043
Trifecta (positive)	0.35	0.20–0.50	*<0.001*	0.47	0.32–0.62	<0.001

CI = confidence interval; OR = odds ratio.

likely to undergo PN over time. Similarly, Leppert et al [17] investigated the trends of PN using the Veterans Health Administration database, and reported that by 2014 two-thirds of patients aged <45 yr underwent PN, compared with one-fourth of patients aged >75 yr.

We utilized trifecta as a composite measure of surgical quality and renal functional outcome for our cohort. Different definitions of trifecta exist [14,18,19]. In 2012, Buffi and colleagues [18] proposed the term "MIC (margin, ischemia, complications)" for the optimal outcomes for PN with the following criteria: ischemia time ≤20 min, no positive surgical margins, and no major complications (Clavien ≥3). In 2013, Hung et al [14] proposed the term 'trifecta (negative surgical margins, no urological complications, and minimal renal functional decrease)' and reported results of patients who underwent PN in four chronological eras of PN procedure using trifecta as an outcome measure. Khalifeh et al [19] defined trifecta as a combination of negative surgical margin, no perioperative complications, and ischemia time <25 min. We utilized the definition of Hung et al [14] due to the inclusion of a functional component as part of the definition, which provided the opportunity to analyze a composite quality of care outcome with surgical, oncological, and functional domains. Our overall trifecta rate was 40.4%, which is similar to the trifecta rates (44%–68%) reported by Hung et al [14] with a younger patient cohort. This suggests that PN in select elderly patients can be associated with comparable outcomes to PN in the generalized RCC patient cohort.

By being a driver of complications and functional outcomes, tumor morphometry is a key determinant in achievement of trifecta outcomes. In our MVA for factors associated with major urologic complications, RENAL score was associated with major urologic complications ($p = 0.043$) and trifecta achievement ($p = 0.007$). Association of increasing tumor complexity, as reflected by RENAL score or other morphometric indices such as PADUA score, with increased risk of complications, ischemia time, and renal dysfunction has been well described [20–22]. Zargar et al [23] compared 1185 robotic and 646 laparoscopic PN for achievement of trifecta (WIT ≤25 min, no complications, and negative surgical margin) and demonstrated complex RENAL score (10–12) to be associated with lack of achievement of trifecta when compared with simple (4–6) RENAL score (hazards ratio 0.6, $p = 0.037$) [23]. Similarly, we noted that achievement of trifecta was associated with decreasing RENAL score (OR 1.26, $p = 0.007$). In a follow-up investigation, Zargar et al [23] analyzed 351 patients undergoing minimally invasive PN who underwent renal scan pre- and postoperatively and noted that achievement of trifecta as defined by Hung et al [14] ($p = 0.014$) or MIC ($p < 0.0001$) was a significant clinical factor predicting ipsilateral split function preservation, suggesting that composite outcomes of surgical quality may be also determinants of predicting functional outcomes [24]. Our finding that achievement of trifecta was protective with respect to CKD upstaging (OR 0.47, $p < 0.001$) further supports this.

Concerns regarding impact of the procedure-specific complication profile of PN in a high-risk patient population have been a historical barrier to consideration of PN in elderly populations. Recently, Vartolomei et al [25] analyzed quality outcomes in 52 patients with median age of 74 yr who underwent robotic PN and noted a complication rate of 15.4%. These findings are very similar to our findings of intra- (6.7%) and postoperative (16.1%) complication rates, which are comparable with Zargar et al [23] who reported 3.2% intraoperative and 16.9% postoperative complication rates in a multi-institutional comparison of 1831 patients undergoing laparoscopic and robotic PN whose mean age was <60. Fero et al [26] analyzed 43749 patients who underwent PN for cT1a–cT2a RCC between 2004 and 2013 utilizing the National Cancer Database and utilized 30-d readmission rate as a quality indicator and noted 30-d readmission rates of 3.9–.1% (similar to our rate of 2.9% overall) and reported that age (OR 1.0, $p = 0.48$) was not an independent predictor for 30-d readmission. Taken together, these findings suggest that decision to proceed with PN should be based on an individualized competing risk analysis of comorbid and oncological risk and that age

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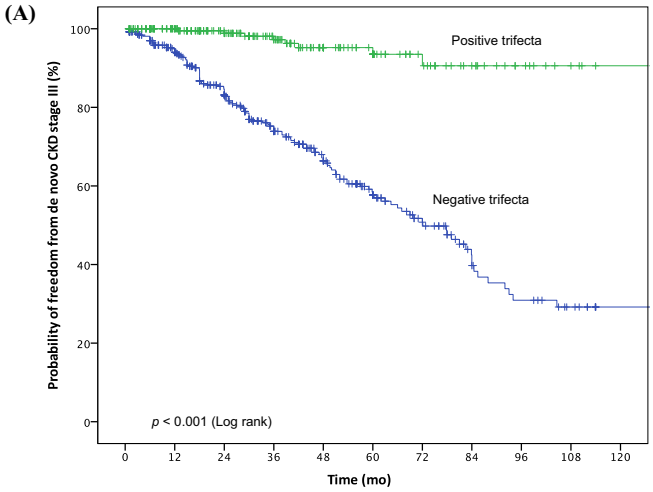
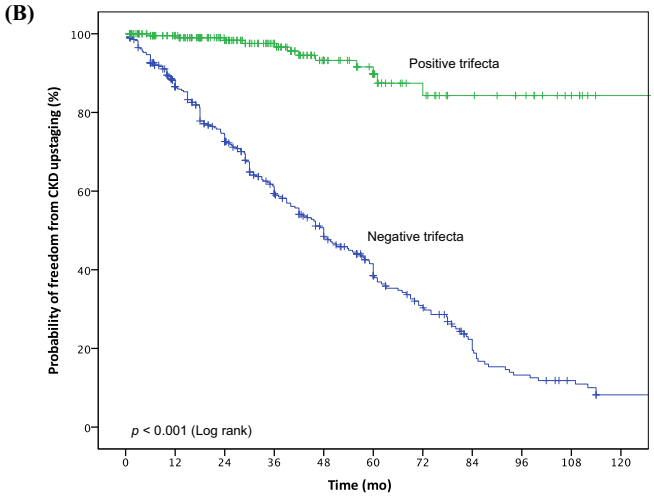


Time (mo)	0	12	24	48	60	120
Positive trifecta, no at risk	264	198	152	73	55	3
Negative trifecta, no at risk	389	306	233	124	81	5

	Positive trifecta	Negative trifecta
1-yr probability (%)	99.5	94
5-yr probability (%)	93.5	57.7
10-yr probability (%)	90.6	29.2



Time (mo)	0	12	24	48	60	120
Positive trifecta, no at risk	264	192	144	68	50	3
Negative trifecta, no at risk	389	270	212	116	80	7

	Positive trifecta	Negative trifecta
1-yr probability (%)	99	88.2
5-yr probability (%)	89.8	41.5
10-yr probability (%)	84.3	8.2

Fig. 2 – Kaplan–Meier analyses according to trifecta status for (A) freedom from de novo chronic kidney disease (CKD) stage 3 and (B) freedom from CKD upstaging.

should not be the singular determinant in the shared decision-making process.

Our study is limited by retrospective design with inherent biases therein, as well as heterogeneous technique and selection criteria. Our large cohort and multicenter and international design confer confidence to the validity of our findings. Comparator groups of RN and AS were not present. RN has been well described as having decreased

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risk of procedure-specific complications [27,28], and AS is associated with low morbidity and risk, particularly in patients with tumor size <2–3 cm [5]. Nonetheless, mean tumor size in our cohort was 3.5 cm, above the 2-cm threshold recommended for AS in guidelines and meta-analyses [5], and the purpose of our study was to evaluate quality of PN in elderly patients, when treatment was indicated and with intent to treat. We noted that our complication rates were similar to contemporary series reported with younger average patient age. Furthermore, our study was limited by the fact that we could not analyze/utilize sensitive measures such as renal flow scan which may have provided more granular information about ipsilateral functional recovery or contralateral compensation [29]. Nonetheless, functional evaluation using eGFR as a surrogate is an acceptable method and well-utilized in guidelines and landmark publications on functional outcomes [15,27,28,30]. While further investigation is requisite to confirm our findings, our data support the emerging paradigm of localized renal mass management where decision to proceed with nephron-sparing surgery should be predicated on shared decision-making and individualized counseling based on competing risks of mortality, and that if indicated, PN in an elderly population may be performed with quality outcomes similar to younger patients.

5. Conclusion

PN in elderly patients was performed with acceptable quality outcomes. Achievement of trifecta is driven by tumor complexity and predicted longer-term functional outcomes.

Author contributions: Ithaar H. Derweesh has full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
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Drafting of Manuscript: Bindayi, Derweesh.
Critical Revision of manuscript for important intellectual content: Autorino, Capitanio, Pavan, Mir, Antonelli, Takagi, Bertolo, Maurer, Rha, Long, Yang, Schips, Lima, Breda, Tanabe, Porpiglia, Montorsi, Derweesh, Linares, Celia, Nunzio, Dobbs.
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Obtaining funding: Derweesh.
Administrative, technical, or material support: Patel, Bindayi, Ryan, Hamilton, Tracey, Dobbs.
Supervision: Derweesh, Autorino.
Other: None.

Financial disclosures: Ithaar H. Derweesh certifies that all conflicts of interest, including specific financial interests and relationships and affiliations relevant to the subject matter or materials discussed in the manuscript (eg, employment/affiliation, grants or funding, consultancies, honoraria, stock ownership or options, expert testimony, royalties, or patents filed, received, or pending), are the following: None.

Funding/Support and role of the sponsor: Stephen Weissman Kidney Cancer Research Fund. The specific role of the funding organization or sponsor is as follows: Management of the data.

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