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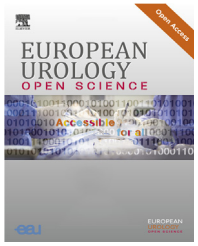

European Association of Urology

Renal Disease

The IRON Study: Investigation of Robot-assisted Versus Open Nephron-sparing Surgery

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Abstract

Background: Current literature does not provide large-scale data regarding clinical outcomes of robot-assisted (RAPN) versus open (OPN) partial nephrectomy. Moreover, data assessing predictors of long-term oncologic outcomes after RAPN are scarce.
Objective: To compare perioperative, functional, and oncologic outcomes of RAPN versus OPN, and to investigate the predictors of oncologic outcomes after RAPN.
Design, setting, and participants: This study included 3467 patients treated with OPN (n = 1063) or RAPN (n = 2404) for a single $cT_{1-2}N_0M_0$ renal mass from 2004 to 2018 at nine high-volume European, North American, and Asian institutions.
Outcome measurements and statistical analysis: The study outcomes were short-term postoperative, functional, and oncologic outcomes. Regression models investigated the effect of surgical approach (open vs Robot assisted) on study outcomes, and interaction tests were used for subgroup analyses. Propensity score matching for demographic and tumor characteristics was used in sensitivity analyses. Multivariable Cox-regression analyses identified predictors of oncologic outcomes after RAPN.

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Results and limitations: Baseline characteristics were similar between patients receiving RAPN and OPN, with only few differences. After adjusting for confounding, RAPN was associated with lower odds of intraoperative (odds ratio [OR]: 0.39, 95% confidence interval [CI]: 0.22, 0.68) and Clavien-Dindo $\geq$2 postoperative (OR: 0.29, 95% CI: 0.16, 0.50) complications (both $p < 0.05$). This association was not affected by comorbidities, tumor dimension, PADUA score, or preoperative renal function (all $p > 0.05$ on interaction tests). On multivariable analyses, we found no differences between the two techniques with respect to functional and oncologic outcomes (all $p > 0.05$). Overall, there were 63 and 92 local recurrences and systemic progressions, respectively, with a median follow-up after surgery of 32 mo (interquartile range: 18, 60). Among patients receiving RAPN, we assessed predictors of local recurrence and systemic progression with discrimination accuracy (ie, C-index) that ranged from 0.73 to 0.81.

Conclusions: While cancer control and long-term renal function did not differ between RAPN and OPN, we found that the intra- and postoperative morbidity—especially in terms of complications—was lower after RAPN than after OPN. Our predictive models allow surgeons to estimate the risk of adverse oncologic outcomes after RAPN, with relevant implications for preoperative counseling and follow-up after surgery.

Patient summary: In this comparative study on robotic versus open partial nephrectomy, functional and oncologic outcomes were similar between the two techniques, with lower morbidity—especially in terms of complications—for robot-assisted surgery. The assessment of prognosticators for patients receiving robot-assisted partial nephrectomy may help in preoperative counseling and provides relevant data to tailor postoperative follow-up.

1. Introduction

There is growing interest toward robot-assisted partial nephrectomy (RAPN) for patients with renal cancer, with the rate of partial nephrectomies performed robotically that increased from 21% in 2009 to 58% in 2015 only in the USA [1]. However, despite the increasing adoption of this surgical technique, large evidence comparing RAPN with other surgical approaches is limited, and long-term oncologic outcomes of patients undergoing RAPN are, virtually, unknown.

Comparative studies are a key step in the introduction and dissemination of new surgical techniques. While prospective, comparative evidence is available for robot-assisted radical prostatectomy [2] and robot-assisted radical cystectomy [3], this is not the case for RAPN. Prior retrospective studies suggested that, as compared with open partial nephrectomy (OPN), RAPN might be associated with more favorable perioperative [4,5] and functional outcomes [6], with data from our group showing that this benefit might hold true also in patients with several comorbidities and/or complex tumors [7,8]. However, common limitations of these papers are the relatively small sample size, missing information on surgeon's experience, and inclusion of patients treated mainly at European institutions. As a result, prospective, high-quality data on the comparison between RAPN and OPN are currently lacking.

Among determinants of successful surgery, oncologic outcomes are the first matter of concern in cancer surgery. In this regard, evidence on the long-term oncologic outcomes of RAPN is scarce. Research questions such as whether RAPN might allow for similar long-term cancer control to OPN and what the meaningful prognosticators are for this patient population are often underinvestigated.

Based on these premises and to address these voids, we built a large multi-institutional database with prospective data collection including patients treated with either OPN or RAPN at nine high-volume centers worldwide.

2. Patients and methods

2.1. Data source and patient selection

The current study relied on prospectively maintained databases from nine tertiary health care institutions worldwide, including 5032 patients treated with partial nephrectomy from 2004 to 2018 (complete inclusion/exclusion criteria are described in Supplementary Fig. 1). For the scope of this study, we focused on patients who underwent RAPN or OPN for a single $cT_{1-2}N_0M_0$ renal mass (n = 4201). We excluded 734 patients with missing information on tumor complexity, leaving 3467 (2404 RAPN and 1063 OPN) patients eligible for the analyses. The surgical approach was selected according to the surgeon's choice. Systemic staging was performed using conventional imaging (computed tomography/magnetic resonance imaging scan) according to internal practice at each treating institution. All information was obtained with appropriate ethics committee or institutional review board waivers, and data were made anonymous before analysis.

2.2. Research hypotheses and outcomes of interest

Our main goals were twofold. First, we wanted to compare intra-, peri-, and postoperative outcomes of OPN and RAPN. In this regard, the study outcomes were as follows:

Intra- and post-operative outcomes: intraoperative complications; estimated blood loss (eBL); operative time; postoperative complications, including overall and grade-specific complications according to the Clavien-Dindo (CD) classification [9], hemorrhagic events, and urinary leakages; and length of stay

Functional outcomes: warm ischemia time and postoperative estimated glomerular filtration rate (eGFR), defined according to the Chronic Kidney Disease Epidemiology Collaboration equation for patients aged <70 yr and the Berlin Initiative Study formula for patients aged ≥70 yr [10], and measured at the last determination before discharge and 1 yr after surgery

Pathologic and oncologic outcomes: positive surgical margins, local recurrence (LC; defined as evidence of disease in the resection bed), systemic progression (SP; defined as evidence of disease elsewhere than the treated kidney), and cancer-specific and all-cause mortality; vital status and cause of death were identified from death certificates and physician correspondence

Our second aim was to investigate long-term oncologic outcomes of patients treated with RAPN, and to assess the predictors of disease recurrence (namely, LC and SP) after RAPN.

To test these research hypotheses, we performed dedicated power analyses that are described in Supplementary Table 1.

2.3. Covariates

Covariates consisted of age at surgery, preoperative eGFR, clinical tumor size, pathologic tumor size, year of surgery, Charlson Comorbidity Index (CCI), gender, tumor side, tumor grade, positive surgical margins, and specific institution. Tumor complexity was determined by the treating urologist using individual PADUA score items (ie, longitudinal location, rim location, renal sinus involvement, relationship with urinary collecting system, and exophytic rate), resulting in the total PADUA score. Finally, for each individual patient, surgical experience was defined as the total number of RAPNs/OPNs performed by the surgeon before the patient's operation [11,12].

2.4. Statistical analyses

Our analyses included several steps. We first compared baseline characteristics of patients receiving OPN versus RAPN. Subsequently, we investigated the effect of surgical approach (robot assisted vs open) on study outcomes using multivariable linear, logistic, and Cox-regression analyses. For all models, the adjustment for confounding included the following variables: age, CCI (0 vs 1 vs 2 vs ≥3), gender, preoperative eGFR, clinical tumor size, tumor side, total PADUA score, year of surgery, and institution.

Given the high risk of postoperative complications after partial nephrectomy [13], we focused specifically on this outcome and utilized regression-derived coefficients to estimate the risk of overall postoperative complications after RAPN and, in separate analyses, after OPN. In addition, a locally weighted scatter plot smoothing method was used to graphically explore the risk of overall complications after RAPN and OPN according to PADUA score, CCI, clinical tumor size, and preoperative eGFR. Finally, since the association between surgical approach and postoperative complications might be different in selected subgroups (namely, patients with a high PADUA score, a high CCI, large tumors, and a low preoperative eGFR), we tested this hypothesis using an interaction term between treatment type (robot assisted vs open) and these factors individually.

Since the chances of receiving OPN or RAPN might be influenced by baseline characteristics of the patients [14,15], the above analyses were repeated after 1:1 propensity score matching. Propensity scores were computed using a logistic regression model with the odds of receiving OPN as the dependent variable and age at diagnosis, gender, CCI, clinical tumor size, tumor side, total PADUA score, any individual PADUA score item, and year of surgery as independent variables. Moreover, the same analyses were repeated after accounting for surgeon's experience in each specific surgical approach.

To assess long-term oncologic outcomes after RAPN, we focused on patients who underwent RAPN with available follow-up status (n = 1687). We utilized Cox-regression analyses to predict LC and SP in pre- and postoperative settings. Given the low number of events among patients receiving RAPN (n = 20), predictors of cancer-specific mortality were not investigated. In the preoperative model, the adjustment for casemix included variables available before surgery such as age at diagnosis, gender, clinical tumor size, and total PADUA score. The postoperative model included age at diagnosis, gender, pathologic tumor size, pathologic tumor grade (G_{3-4} vs G_{1-2}), type of malignant histology (clear cell renal cell carcinoma vs other), and positive surgical margins (no vs yes). Moreover, since we found evidence of a stage migration toward more aggressive disease over the period of study (Supplementary Table 2), we included year of surgery in our models as a continuous variable. To allow for an adequate estimation of the risk of cancer recurrences, the postoperative model included only patients with confirmed malignancy on final pathology (n = 1333). For both models, the estimation accuracy was assessed using the C-index.

3. Results

3.1. Descriptive characteristics

Descriptive characteristics of the study population are listed in Table 1. A total of 2404 (69%) patients underwent RAPN. As compared with patients treated with OPN, those receiving RAPN were younger (median: 61 vs 65 yr) with a higher preoperative eGFR (median: 84 vs 80 ml/min/1.73 m^2), had a smaller clinical tumor (median: 3.0 vs 3.2 cm), and were operated more recently (46% vs 16% from 2015 to 2018; all $p < 0.001$).

3.2. Comparison between RAPN and OPN

3.2.1. Intra- and postoperative outcomes

Results for intra- and postoperative outcomes are described in Table 2. After adjusting for confounding, patients receiving RAPN had lower eBL than those who underwent OPN (estimate [EST]: −140, 95% confidence interval [CI]: -163, −115), whereas operative time was longer in the RAPN group (EST: +31, 95% CI: +26, +36; both $p < 0.001$). Length of hospital stay was shorter after RAPN than after OPN (EST: −2, 95% CI: −2, −1; $p < 0.001$).

3.2.2. Complications

A total of 139 (6%) and 99 (9%) patients had intraoperative complications in the RAPN versus OPN group, respectively (Table 2). As compared with OPN, patients receiving RAPN had a lower rate of overall (18% vs 33%) and CD ≥2 (12% vs 20%) complications. After adjusting for confounding, RAPN was associated with lower odds of intraoperative (odds ratio [OR]: 0.39, 95% CI: 0.22, 0.68), overall (OR: 0.51; 95% CI: 0.33, 0.76), and CD ≥2 (OR: 0.29; 95% CI: 0.16, 0.50) postoperative complications than OPN (all $p < 0.05$). As shown in Figures 1A–D, these findings were not affected by PADUA score, CCI, clinical tumor size, or

Table 1 – Descriptive characteristics of 3467 patients treated with robot-assisted (RAPN) or open (OPN) partial nephrectomy for a single cT1-T2 renal mass at nine institutions during 2004–2018

Variable	RAPN (n = 2404; 69%)	OPN (n = 1063; 31%)	p value
Age (yr)	61 (51, 69)	65 (54, 72)	<0.001
Gender, male	1502 (63)	690 (65)	0.1
CCI			
0	845 (35)	356 (34)	0.5
1	416 (17)	204 (19)	
2	602 (25)	270 (25)	
≥3	541 (23)	233 (22)	
eGFR (ml/min/1.73 m^2)	84 (65, 97)	80 (62, 94)	<0.001
Single kidney	77 (3)	52 (5)	0.02
Clinical size (cm)	3.0 (2.0, 4.2)	3.2 (2.4, 4.3)	<0.001
Clinical stage			
cT1a	1744 (73)	762 (72)	0.4
cT1b	563 (23)	245 (23)	
cT2	98 (4)	56 (5)	
Tumor side, left	1155 (48)	502 (47)	0.7
PADUA score	8 (7, 10)	8 (7, 9)	<0.001
PADUA risk class			
High	1039 (43)	426 (40)	0.2
Medium	644 (27)	307 (29)	
Low	721 (30)	330 (31)	
Year of surgery			
2004–2011	556 (23)	596 (56)	<0.001
2012–2014	745 (31)	295 (28)	
2015–2018	1103 (46)	172 (16)	
Pathologic size (cm)	3.0 (2.0, 4.1)	3.0 (2.1, 4.0)	0.1
Malignancy on final pathology	1920 (80)	834 (78)	0.7
T3-T4 on final pathology	107 (4.4)	51 (4.7)	0.8
G3-G4 on final pathology	550 (23)	191 (18)	0.3
Median follow-up for survivors (mo)	24 (14–47)	62 (30–100)	0.001

CCI = Charlson Comorbidity Index; eGFR = estimated glomerular filtration rate.
Numbers are frequencies (proportions) and medians (interquartile range).

preoperative eGFR (all $p > 0.05$ on interaction tests). Similarly, our results were unaltered in sensitivity analyses after propensity score matching (Supplementary Table 3) and after the inclusion of surgical experience (Supplementary Table 4).

3.2.3. *Renal function*

Despite slightly longer warm ischemia time and a lower postoperative eGFR in patients treated with RAPN than in those treated with OPN, we did not find evidence of a difference with respect to 1-yr eGFR between the two surgical approaches (adjusted estimate for RAPN vs OPN: −1; 95% CI: −2, +1; $p = 0.5$; Table 2).

3.2.4. *Oncologic outcomes*

A total of 103 (4%) and 55 (5%) patients had positive surgical margins in the RAPN versus OPN group, respectively. On multivariable analyses, the odds of positive surgical margins were lower for patients receiving RAPN versus OPN (odds ratio [OR]: 0.53; 95% CI: 0.27, 0.99; $p = 0.05$).

Among 2301 patients with available follow-up data, there were 46 cancer deaths. A total of 63 and 92 patients had LC and SP, respectively. The median (interquartile range) follow-up for survivors was 32 (18, 60) mo. On multivariable analyses, we did not find evidence of an association between surgical approach (RAPN vs OPN) and all oncologic outcomes (all $p > 0.05$; Table 2).

3.3. *Predictors of oncologic outcomes after RAPN*

Table 3 describes the results of our multivariable models for the prediction of oncologic outcomes after RAPN. In the

Table 2 – Clinical outcomes of 3467 patients treated with robot-assisted (RAPN) and open (OPN) partial nephrectomy for a cT1–2 renal mass

Outcome	RAPN (n = 2404)	OPN (n = 1063)	RAPN vs OPN OR/EST/HR (95% CI)	p value
Intraoperative outcomes				
Estimated blood loss (ml)	150 (100, 300)	180 (100, 350)	−140 (−163, −115)	<0.001
Operative time (min)	150 (120, 200)	120 (100, 163)	+31 (+26, +36)	<0.001
Intraoperative complications	139 (6)	99 (9)	0.39 (0.22, 0.68)	<0.001
Postoperative outcomes and complications				
Overall complications	435 (18)	355 (33)	0.51 (0.33, 0.76)	0.001
Clavien-Dindo complications				
≥2	279 (12)	215 (20)	0.29 (0.16, 0.50)	<0.001
≥3	97 (4)	65 (6)	0.26 (0.08, 0.65)	0.008
Hemorrhagic complications	155 (6)	96 (9)	0.22 (0.08, 0.52)	0.001
Urinary leakage	21 (1)	49 (5)	0.08 (0.02, 0.21)	<0.001
Length of stay (d)	4 (3, 5)	6 (5, 7)	−2 (−2, −1)	<0.001
Functional outcomes				
Off-clamp procedure	280 (12)	200 (19)	0.32 (0.25, 0.41)	0.0001
Warm ischemia time (min)	16 (11, 22)	15 (8, 21)	+4.3 (+3, +5)	<0.001
Postoperative eGFR	76 (60, 89)	78 (63, 93)	−6 (−8, −4)	<0.001
1-yr eGFR	71 (56, 88)	68 (55, 87)	−1 (−2, +1)	0.5
Oncologic outcomes[a]				
Positive surgical margins	103 (4)	55 (5)	0.53 (0.27, 0.99)	0.05
Local recurrence	97% (95%, 98%)	96% (95%, 98%)	1.02 (0.51, 2.04)	0.9
Systemic progression	94% (92%, 96%)	92% (89%, 94%)	1.18 (0.61, 2.29)	0.6
Cancer-specific mortality	97% (96%, 99%)	98% (97%, 99%)	0.99 (0.33, 2.90)	0.9

CI = confidence interval; eGFR = estimated glomerular filtration rate; EST = estimate; HR = hazard ratio; OR = odds ratio; RCC = renal cell carcinoma.
All p-values refer to the association between surgical approach (robotic vs. open) and each outcome of interest, with the open approach as reference group. Data are presented as frequency (proportion) and median (interquartile range) for categorical and continuous variables, respectively. Estimated GFR is described as ml/min/1.73 m^2. Multivariable models were adjusted for age, Charlson Comorbidity Index, gender, preoperative eGFR, clinical size, tumor side, PADUA score, year of surgery, and institution.
[a] Time-dependent outcomes are shown as probability of freedom from the event at 5 yr (95% confidence interval) using Kaplan-Meier estimates, and are calculated for patients with available follow-up and confirmed RCC on final pathology (n = 994 and n = 778 in the RAPN and OPN group, respectively)

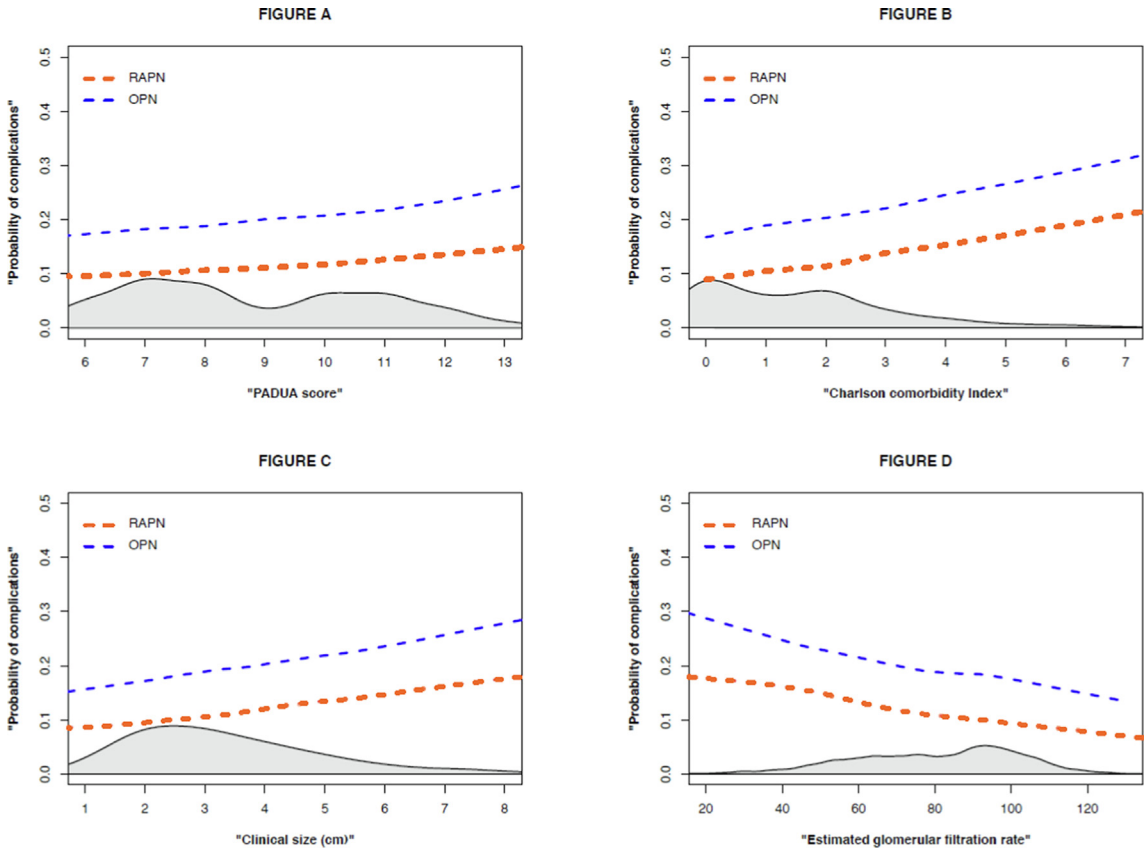

Fig. 1 – Overall risk of complications after robot-assisted (RAPN) or open (OPN) partial nephrectomy stratified according to (A) preoperative PADUA score, (B) Charlson Comorbidity Index, (C) clinical size, and (D) preoperative estimated glomerular filtration rate (ml/min/1.73 m^2). Gray areas represent the distribution for the respective parameter. The risk of complications according to each individual characteristic was computed for 3467 patients treated with RAPN or OPN using an interaction term between the characteristic of interest and surgical approach (robot assisted vs open) included in a multivariable regression model adjusted for age, PADUA score, clinical size, Charlson Comorbidity Index, and preoperative estimated glomerular filtration rate.

preoperative setting, women had lower hazards of LC (hazards ratio [HR]: 0.41, 95% CI: 0.18, 0.95), whereas older patients (HR: 1.03, 95% CI: 1.00, 1.06; $p = 0.02$) and patients with a larger clinical tumor (HR: 1.25, 95% CI: 1.07, 1.47; $p = 0.004$) were associated with higher hazards of LC (Table 3).

On multivariable analyses assessing the predictors of SP, only clinical tumor size was an independent predictor of a higher risk of SP (HR: 1.20, 95% CI: 1.01, 1.43; $p = 0.03$). The discrimination accuracy—the C-index—of our preoperative models was moderate, ranging from 0.73 to 0.77.

In our postoperative models, pathologic tumor size (HR: 1.21, 95% CI: 1.14, 1.44), pathologic grade (HR: 3.54, 95% CI: 1.66, 7.56), clear cell histology (HR: 3.26, 95% CI: 1.23, 8.60), and positive surgical margins (HR: 3.85, 95% CI: 1.55, 9.52; all $p < 0.05$; Table 3) were associated with higher hazards of LC.

With respect to SP, patients with a larger pathologic tumor had higher hazards of SP (HR: 1.26, 95% CI: 1.08, 1.47; $p = 0.003$). The discrimination accuracy of our postoperative models ranged from 0.79 to 0.81.

4. Discussion

In this study, we analyzed one of the largest comparative series on OPN and RAPN. While functional and oncologic outcomes did not differ significantly between RAPN and OPN, surgical morbidity—especially in terms of complications, blood loss, and hospital stay—favored robotic surgery as compared with open surgery.

Evidence suggesting that minimally invasive techniques allow for better perioperative outcomes after partial nephrectomy than open surgery is increasing [16,17], and our results are consistent with prior investigations [18]. That said, it is still unclear which is the compelling indication for either a surgeon or an institution to switch from open to minimally invasive surgery [19]. The debate centers on whether the transition to robotic surgery might translate into better long-term functional outcomes [20]. Our results add significantly to the current literature, suggesting that the functional results after RAPN are similar to those after OPN, with the obvious advantages of reduced morbidity. Still, besides these clinical factors, there are also concerns about the costs of robotic surgery that have often contained its broad adoption. In this regard, the introduction of novel robotic platforms [21–23] may mitigate this limitation, expanding the availability of robotic surgery. Finally, another factor that might favor the transition to robotic surgery is recent evidence on robot-assisted radical prostatectomy showing that robotic surgery might have the potential to flatten the learning curve, allowing surgeons to reach adequate outcome in an early phase of their career

Table 3 – Multivariable Cox-regression models predicting local recurrence and systemic progression after RAPN relying on pre- and postoperative predictors

Predictors	Outcome of interest			
	Local recurrence		Systemic progression	
	HR (95% CI)	*p* value	HR (95% CI)	*p* value
Preoperative model (n = 1687, patients treated with RAPN with available follow-up data)				
Age at diagnosis	1.03 (1.00, 1.06)	0.02	1.00 (0.97, 1.03)	0.8
Gender				
Male	Ref.	0.03	–	0.07
Female	0.41 (0.18, 0.95)		0.48 (0.22, 1.07)	
Clinical tumor size	1.25 (1.07, 1.47)	0.004	1.20 (1.01, 1.43)	0.03
PADUA score	1.09 (0.89, 1.33)	0.4	1.17 (0.95, 1.43)	0.1
Year of surgery	0.91 (0.79, 1.05)	0.2	0.91 (0.78, 1.05)	0.2
C-index	0.73		0.77	
Postoperative model (n = 1333, patients with malignancy on final pathology after RAPN with available follow-up data)				
Age at diagnosis	1.01 (0.99, 1.05)	0.2	0.98 (0.96, 1.01)	0.4
Gender				
Male	Ref.	0.1	–	0.4
Female	0.53 (0.23, 1.25)		0.71 (0.33, 1.53)	
Pathologic tumor size	1.21 (1.14, 1.44)	0.033	1.26 (1.08, 1.47)	0.003
Pathologic tumor grade				
G_{1-2}	Ref.	0.001	–	0.1
G_{3-4}	3.54 (1.66, 7.56)		1.67 (0.83, 3.37)	
Type of malignant histology				
Other	Ref.	0.01	–	0.1
Clear cell RCC	3.26 (1.23, 8.60)		2.10 (0.85, 5.15)	
Positive surgical margins				
No	Ref.	0.003	–	0.7
Yes	3.85 (1.55, 9.52)		1.28 (0.30, 5.40)	
Year of surgery	0.88 (0.75, 1.03)	0.1	0.93 (0.79, 1.09)	0.4
C-index	0.81		0.79	

CI = confidence interval; HR = hazards ratio; RCC = renal cell carcinoma; Ref. = reference.

[12,24]. Whether this might apply to partial nephrectomy—a different operation, with wider variability and different challenges [25]—is open to discussion and should be investigated in future studies.

Oncologic control is always a concern in cancer surgery. In this regard, our data showed that oncologic outcomes, including surgical margins rates, were not different between patients receiving RAPN and OPN. Moreover, our results have relevant implications for clinical practice as we provided long-term data on predictors of oncologic outcomes after RAPN [26], allowing surgeons to adequately counsel patients before and after surgery.

Our findings have several limitations. First, despite data being prospectively collected, the analyses were performed in a retrospective manner. Moreover, although we adjusted for clinical characteristics, we cannot completely rule out residual confounding by differences in case mix. Such confounding could have resulted from surgeons with different levels of experience for each surgical technique. However, we repeated the analyses after the inclusion of approach-specific surgical experience, with no difference in results. in addition, our study included patients operated over a long period, and thus, practice changes at different institutions might not have been captured by our data collection, and it is possible that our findings might not entirely be transferable to contemporary patients. We similarly did not have follow-up data available for the entire cohort. Moreover, although our models included the type of resection, this information was not reported through a standardized instrument such as the surface-intermediate-base score [27], resulting in possible inaccuracy across centers. We also acknowledge that our study did not include a cost analysis. Given the lack of European Association of Urology recommendations in favor of a specific surgical approach for partial nephrectomy, an increasing number of comparative studies investigated whether minimally invasive surgery might represent a new standard of surgical care. However, since prior evidence showed different economic implications according to the operating technique [28], a fair comparison between surgical approaches should include their costs. Since the multi-institutional nature of our study may have limited the availability of such data, further research should address this issue.

5. Conclusions

We compared the outcomes of RAPN and OPN in one of the largest series on partial nephrectomy. While cancer control and long-term renal function did not differ between the techniques, we found that the intra- and postoperative morbidity—especially in terms of complications—were lower after RAPN than after OPN. Our predictive models allow surgeons to estimate the risk of adverse oncologic outcomes after RAPN with optimal predictive accuracy, with relevant implications for preoperative counseling and follow-up after surgery. The global setting of the study, the relatively long follow-up, and the large population with thorough clinical data collection (including contemporary patients treated in the postdissemination era of RAPN) are unique strengths of this study and support the validity of the observed findings.

Author contributions: Alessandro Larcher had 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.

Study concept and design: Bravi, Larcher.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.euros.2022.12.017.

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