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RESEARCH

Outcomes of open versus robotic partial nephrectomy: a 20-year single institution experience

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Abstract

Robotic assisted partial nephrectomy (RPN) has emerged in urologic practice for the management of appropriately sized renal masses. We provide a 20-year comparison of the outcomes of open partial nephrectomy (OPN) versus RPN for renal cell carcinoma (RCC) at our institution. An IRB-approved retrospective review was conducted of RCC patients at a single institution from 2000 to 2022 who underwent RPN or OPN. In addition to demographics, procedural details including ischemia and operative time were collected. Oncologic outcomes were evaluated through Kaplan–Meier statistical analysis to determine recurrence-free survival (RFS), cancer-specific survival (CSS), and overall survival (OS) analysis. 849 patients underwent RPN while 385 underwent OPN. 61% were male with average age of 58.8 ± 12.8 years. Operative time was shorter in the open group (184 vs 200 min, $p = 0.002$), as was ischemia time (16 vs 19 min, $p = 0.047$). However, after 2012, RPN became more common than OPN with improving ischemia time. RPN patients had significantly improved RFS (HR 0.45, $p = 0.0004$) and OS (HR 0.51, $p = 0.0016$) when controlled for T-stage and margin status. More > pT1 masses were managed with OPN than RPN (11.2 vs 5.4%, $p < 0.0001$). At our institution, RPN had an increasing incidence with reduced ischemia time compared to OPN over the last 10 years. While higher stage renal masses were more often managed with OPN, selective use of RPN does offer improved oncologic outcomes. Further investigation is needed to evaluate optimization of the selection of RPN versus OPN in the nephron-sparing management of renal masses.

Keywords Robotic partial nephrectomy · Open partial nephrectomy · Robotic surgery · Urology · Urologic oncology

Introduction

The partial nephrectomy is a urologic procedure used to treat renal cell carcinoma that has been around for many decades and is currently the standard of care for small renal masses or unique situations where renal function must be prioritized. Although first performed using an open approach, the partial nephrectomy has evolved to include laparoscopic techniques and, most recently, robotic assistance. First described in 2004, the robotic assisted partial nephrectomy (RPN) has rapidly gained popularity amongst urologists and patients. The positive features initially advertised included 3D vision, better precision, enhanced dexterity, and improved ergonomics for the surgeon [1]. However, the outcomes of robotic vs open partial nephrectomies (OPN) were originally unknown.

Today, we have data from retrospective studies and systematic reviews that demonstrate similar oncologic outcomes between OPN and RPN, with some studies concluding that RPN has fewer complications and decreased length of hospital stay [2]. However, no randomized prospective studies have been published to date. Here, we aim to describe the experience of OPN vs RPN for renal cell carcinoma (RCC)

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at a single institution over 20 years and reflect on the resulting survival and outcomes.

Methods

A retrospective review identified patients undergoing PN for RCC at a single institution with data from 15 surgeons from 2000 to 2022. Data was gathered on demographics, procedure metrics, and cancer outcomes. Demographic and clinical characteristics were analyzed using Student's t-tests for Normally distributed continuous variables, Wilcoxon rank-sum tests for skewed continuous data, Chi-Square tests for non-ordinal categorical data, and Mantel–Haenszel tests for ordinal categorical data. Recurrence-free survival (RFS), cancer-specific survival (CSS), and overall survival (OS) analysis was performed using the Kaplan–Meier method to determine the general difference between strata using the log-rank test and then Cox Proportional hazard models were used to find hazard ratios with 95% confidence intervals. Cox models were adjusted for age, pathological staging, creatinine at follow-up, and margin. All analytic assumptions were verified. Analyses were performed using SAS v9.4 (SAS Institute, Cary, NC).

Results

1234 patients had data available for review with median follow up 18 months (range 0–264). Table 1 shows demographics. 61% were male with average age 58.8 ± 12.8 years. Median RENAL score was 7 ± 1.8. Operative time was shorter in the open group (184 vs 200 min, p = 0.002), as was ischemia time (16 vs 19 min, p = 0.046). Most masses were pT1 regardless of technique, but there were more > pT1 masses resected open (11.2 vs 5.4%, p < 0.0001). There were more positive margins (10.3 vs 3.4%, p < 0.0001) and postoperative complications (25.2 vs 12.1%, p < 0.0001) after open resection.

Table 1 Demographics and operative outcomes

	Overall n = 1234	Robot n = 849	Open n = 385	p-value
Gender				
Female	485 (39.3)	338 (39.8)	147 (38.2)	0.6
Male	749 (60.7)	511 (60.2)	238 (61.8)	
Age	58.7 (12.8)	58.7 (12.7)	58.6 (13.0)	0.8
Staging				
pT1a	937 (75.9)	677 (79.7)	260 (67.5)	< 0.0001
pT1b	208 (16.9)	126 (14.8)	82 (21.3)	
pT2a	16 (1.3)	6 (0.7)	10 (2.6)	
pT2b	2 (0.2)	0 (0)	2 (0.5)	
pT3a	70 (5.7)	40 (4.7)	30 (7.8)	
pT3b	1 (0.1)	0 (0)	1 (0.3)	
Creatinine at diagnosis	1.1 (0.5)	1.0 (0.4)	1.1 (0.6)	0.2
Creatinine at last follow up	1.2 (0.9)	1.1 (0.6)	1.4 (1.3)	0.002
Creatinine change	0.2 (0.9)	0.1 (0.6)	0.3 (1.4)	0.01
RENAL nephrometry score	7.0 (1.8)	6.9 (1.8)	7.4 (1.9)	0.002
Ischemia time (min)	19 (0, 82)	19 (0, 68)	16 (0, 82)	0.0466
Procedure length (min)	196 (18, 847)	200 (18, 847)	184 (63, 669)	0.0002
30-day complications	200 (16.2)	103 (12.1)	97 (25.2)	< 0.0001
Clavien score				
1	78 (38.6)	45 (42.9)	33 (34.0)	0.3
2	68 (33.7)	31 (29.5)	37 (38.1)	
3	36 (17.8)	20 (19.1)	16 (16.5)	
4	18 (8.9)	9 (8.6)	9 (9.3)	
5	2 (1.0)	0 (0)	2 (2.1)	
Positive margin	67 (5.6)	28 (3.4)	39 (10.3)	< 0.0001
Follow-up (months)	18 (0, 264)	16.5 (0, 180)	24 (0, 264)	0.03

Values are means (standard deviations) or medians (ranges) for continuous variables and frequencies (percentages) for categorical variables. p-values are from Student's t-test for age, Wilcoxon rank-sum for other continuous variables, Chi-square tests for categorical variables (Mantel–Haenszel for ordinal variables, such as staging and Clavien score). Frequencies may not add to column totals due to missing data

Experience with partial nephrectomy over time

The use of PN increased over time with an increasing use of robotics (Fig. 1). Most surgeons performed primarily either robotic or open procedures, and few surgeons performed both robotic and open procedures regularly (Supplementary Fig. 1). Figure 2 demonstrates trends of overall operative time and ischemia time for the two groups. Prior to 2012, when open partial nephrectomies still outnumbered robotic partial nephrectomies (Fig. 1), open partial nephrectomies were performed more quickly and had less ischemia time compared to robotic partial nephrectomies (Fig. 2). After 2012, this changed and robotic partial nephrectomies became faster with less ischemia time (Fig. 2). The opposite trend was seen for open partials, with increased operative time and longer ischemia time after 2012 (Fig. 2).

Oncologic outcomes

Patients who underwent robotic partial nephrectomies had improved RFS compared with patients who underwent open partial nephrectomies (HR 0.51, 95% CI 0.33–0.78, p = 0.002) even after controlling for T stage, positive margin rate, and whether the patient had multiple renal masses (Fig. 3A). Patients who underwent robotic partial nephrectomies also experienced improved OS (HR 0.51, 95% CI 0.33–0.78, p = 0.002) and CSS (HR 0.32, 95% CI 0.13–0.83, p = 0.02) even after controlling for age, T stage, positive margin, and creatinine at last follow up (Fig. 3B, C).

Discussion

This manuscript describes a single institution's experience with over 1200 partial nephrectomies over the last 20 years. The number of partial nephrectomies performed per year has, expectedly, steadily increased over the past several years, corresponding with a documented increase in the incidence of small renal masses. Robotic partial nephrectomies specifically are increasing in number; the number of open partial nephrectomies performed per year have remained stable since 2016. In terms of outcomes, procedure time and ischemia time have both decreased over time for robotic partial nephrectomies; the opposite trend was seen for open partial nephrectomies. Finally, for cancer-specific outcomes, patients who underwent robotic partial nephrectomy appeared to have improved RFS, CSS, and OS compared to those who underwent open partial nephrectomy.

The increase in partial nephrectomies over time, and specifically the increase in robotic partial nephrectomies over time, has been well established in the literature and has coincided with the increased diagnosis of small renal masses [3]. With the increase in RPNs, it is imperative to understand the outcomes of robotic versus open partial nephrectomy to be able to adequately counsel patients for treatment [4].

In terms of operative parameters, RPN takes 16 min longer (p = 0.0002) to complete the surgery than OPN. However, when this is further broken down into pre 2012 and post 2012 data (Fig. 2), we see that over the last two decades that RPN have taken less surgical time and involve less ischemia time. Post 2012, they are faster than OPN and, interestingly, OPN have increased in operative time and ischemia time. This could be because most simple partial nephrectomies are now done robotically, and the open partial nephrectomies are reserved for more complicated cases and larger masses.

There also was a learning curve when the robotic partial nephrectomy procedure was first introduced, as investigated by Larcher et al. [5]. From the data in our study, the clinical difference in operating times is minimal. This is reinforced by the second endpoint that shows the overall ischemia time was not clinically different between the two groups. This was demonstrated in the study by Tan et al. that had an equal ischemia time between RPN and OPN, despite increased renal artery clamping time in the RPN group [6].

We compared complication rates between the two groups. Consistent with published literature, there were more grade ≥ 3 complications in the OPN group [7]. Other studies have specifically identified decreased estimated blood loss, hospital stay, and ischemia time in the RPN group [1, 8]. Although, renal function on follow up was statistically significantly better after RPN than OPN, this was not clinically significant with OPN patients having an average creatinine 1.4 (eGFR 66) compared to 1.1 (eGFR 70) for RPN patients (p = 0.0016). While some studies have demonstrated a difference in renal function between RPN and OPN, favoring RPN, others have shown no difference [9–12].

For cancer-specific outcomes, RPNs had fewer positive margins than OPNs. Additionally, in our study, RPNs had improved RFS, CSS, and OS when compared to OPNs.

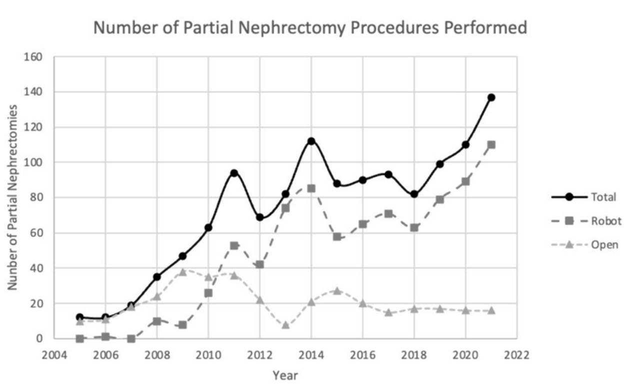

Fig. 1 Total number of partial nephrectomies performed at a single institution from 2005 to 2021

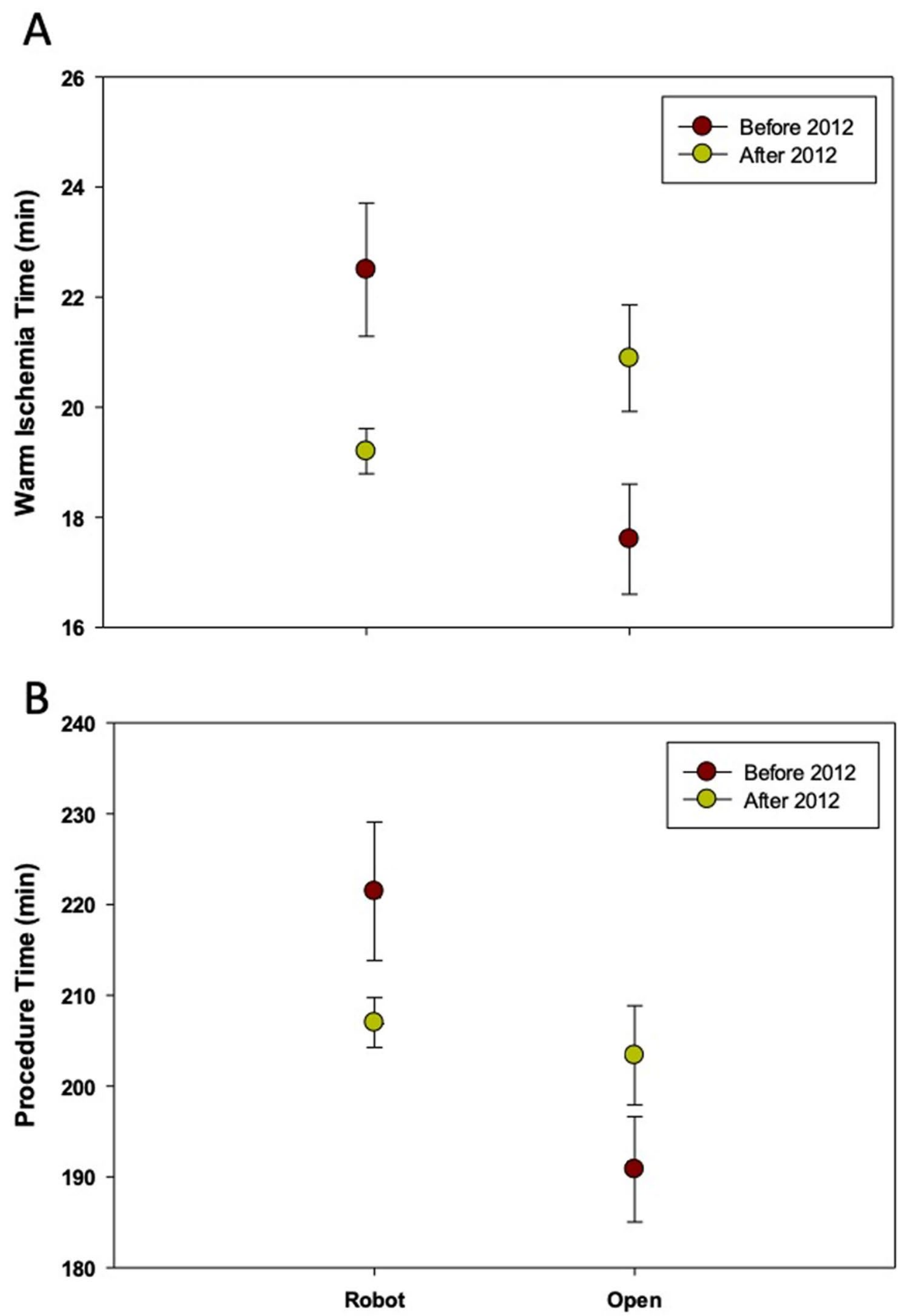

Fig. 2 Comparison of ischemia time and total procedure time in the two groups prior to and after 2012. Both ischemia time (**A**) and procedure time (**B**) decreased in robotic procedures from before and after 2012. The opposite trend was seen for open procedures

This finding persisted on multivariate analysis controlling for T-stage, margin, age, and creatinine at last follow up. Current literature suggests that RPN has similar oncologic outcomes to OPN [13], and no major study has identified a major oncologic advantage of RPN compared to OPN. Due to the retrospective and heterogeneous nature of our study, our cancer-specific findings may be due to other confounding variables. However, continued evaluation as to the best methods by which to select patients for RPN versus OPN is warranted [1, 14, 15].

This study has several limitations. It is a single institution, retrospective study. Although there is high volume, a multi-center, randomized trial would be ideal to compare the two surgical methods. We are also limited in follow up as recurrence free survival is only measured to 20 years post operatively. There is a learning curve associated with robotic surgery that could influence surgical time and outcomes

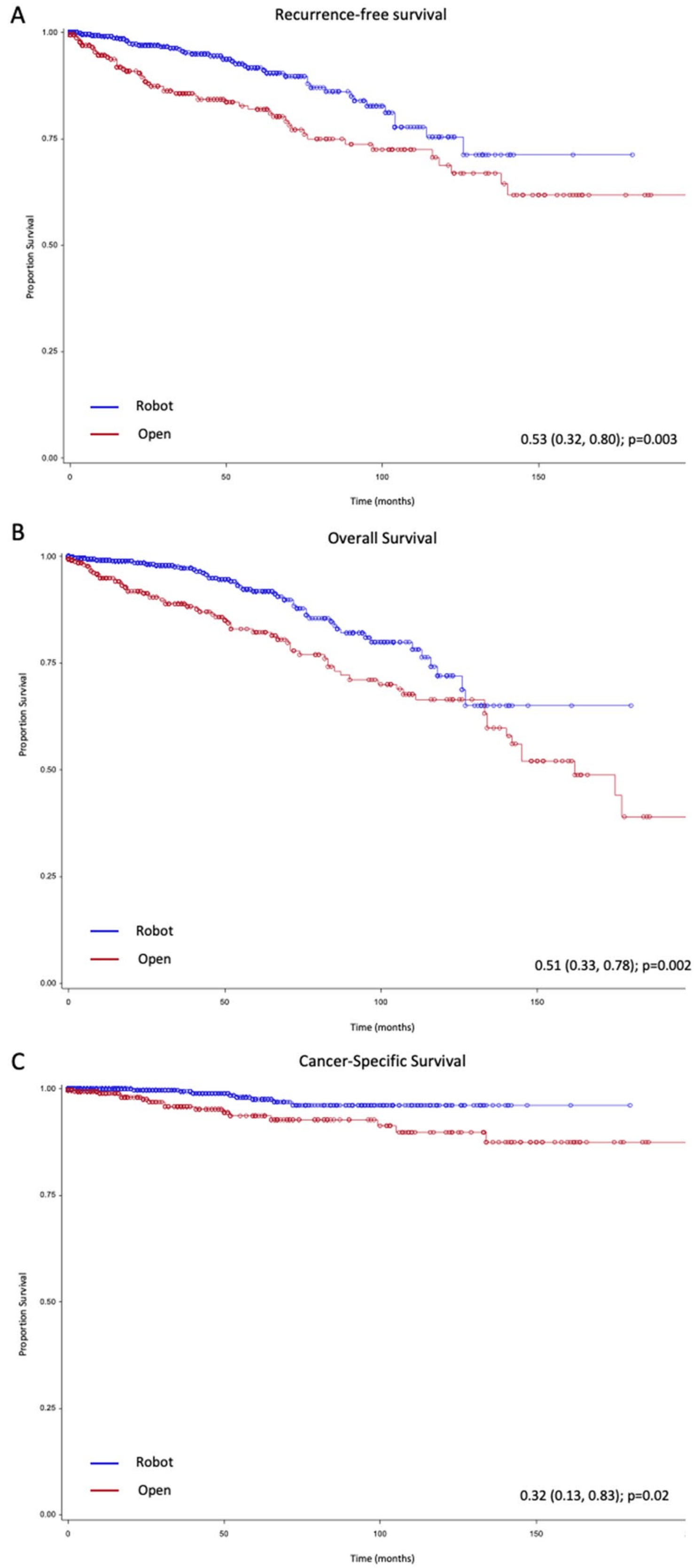

Fig. 3 Recurrence-free, overall, and cancer-specific Kaplan Meier curves by type of procedure. Patients who underwent robotic partial nephrectomies had improved RFS (**A**), OS (**B**), and CSS (**C**) than those who underwent open partial nephrectomies

during the early part of the study. Figure 2 provides some insight in the differences in robotic surgery data in the early part of the study (pre-2012) and later (post-2012).

In conclusion, 20-year experience with PN shows increasing incidence of PN, specifically the robotic approach, with improving operative and ischemia time as RPN becomes more widespread. OPN is being reserved for more complex tumors, with higher T stage masses being treated with OPN and with increasing operative and ischemia time over time. Additional study is needed to evaluate how to optimize the use of and ideal indications for RPN and OPN in nephron-sparing management of renal masses.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors have not disclosed any competing interests.

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