Robotic-assisted laparoscopic partial nephrectomy vs. laparoscopic and open partial nephrectomy: A single-site, two-surgeon, retrospective cohort study

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ABSTRACT

Introduction: In 2019, our center attempted to transition all partial nephrectomies (PNs) to robotic-assisted laparoscopic PN (RALPN). The purpose of this study was to compare RALPN outcomes to laparoscopic PN (LPN) and open PN (OPN) at our institution, as there is limited literature from Canadian centers.

Methods: In this single-center, two-surgeon, retrospective cohort study, we compared RALPN outcomes during the early phase of our robotics program to OPN and LPN performed just before the introduction of RALPN.

Results: A total of 106 patients underwent OPN, 83 LPN, and 82 RALPN during the study period. Median RALPN RENAL score was 7 vs. 6 for LPN ($p<0.05$) and 8 for OPN ($p=0.10$). Median RALPN length of stay (LOS) was two days vs. three and four days for LPN and OPN ($p<0.05$), respectively. OPN median procedure time was 104 minutes vs. 94 and 82 minutes for LPN and RALPN ($p<0.05$), respectively. Median OPN operating room (OR) time was 160 minutes vs. 150 and 146 minutes for LPN and RALPN ($p<0.05$), respectively. There were no significant differences in intraoperative ($p=0.92$) or postoperative complications rates ($p=0.47$). RALPN warm ischemia time (WIT) was 17 minutes vs 14.5 and 15 minutes for OPN and LPN

KEY MESSAGES

- There is limited data from Canadian centers looking at RALPN vs LPN and OPN.
- We compared outcomes of RALPN to LPN and OPN performed at our center in the past.
- We found the RALPN had higher WIT, lower OR time, lower procedure time, lower LOS, and similar rates of complications as LPN and OPN.

($p<0.05$), respectively. Median RALPN estimated blood loss (EBL) was 165 ml vs. 250 ml for OPN ($p<0.05$) and 125 ml for LPN ($p=0.15$).
Conclusions: Although patients who underwent RALPN had longer WIT, they had similar rates of complications, required less total OR time, and had shorter procedure time and LOS compared with OPN and LPN despite similar RENAL score compared to OPN and greater score than LPN.

INTRODUCTION

When technically feasible, partial nephrectomy (PN) has become the preferred treatment approach for most T1 stage renal cell carcinoma (RCC).[1,2] Due to their minimally invasive advantages, laparoscopic and robotic-assisted laparoscopic approaches have been used to perform PNs for small localized renal masses over OPN when indicated. The current Canadian Urological Association (CUA) guidelines state that PN is recommended by open, laparoscopic, or robotic-assisted means, with radical nephrectomy being reserved for tumours that are not amenable to PN.[2] Increasingly, robotic-assisted laparoscopic approaches are being used to perform PNs for small renal masses (SRMs) over traditional open or laparoscopic techniques.

The Queen Elizabeth II Health Sciences Centre (QEII HSC) in Halifax, Nova Scotia Canada, has a long history of expertise in OPN and LPN. In 2019, the Department of Urology introduced a robotics program for the management of urological malignancies with a focus on radical prostatectomy and PN. After the introduction of the robotics program, the department attempted to fully transition to RALPN from its well-established LPN and OPN program for renal masses amenable to PN.

The goal of this single-centre, two-surgeon study is to evaluate whether there is a significant difference in RALPN perioperative outcomes compared to the OPNs and LPNs performed in the past at the QEII HSC by the same two surgeons performing RALPNs at this site. This site-specific comparison and subsequent analysis could provide insight into whether introducing RALPN has led to improved perioperative outcomes at this Canadian centre during the initial phase of its robotics program and add to the growing body of literature looking at comparing RALPN to non-robotic modalities. Although there are studies in the current literature that compare select outcomes of robotic-assisted versus non-robotic-assisted PNs, there is little to no Canadian data available that compares RAPLN to LPN and OPN separately. Also, much of the current literature on RALPN outcomes are from single-surgeon studies. Additionally, robotic-assisted surgeries are an expensive resource, therefore using Canadian-specific data would allow us to analyze whether the use of RALPN for kidney tumours based on perioperative outcomes is justifiable as opposed to non-robotic modalities, particularly LPN, given the nature of Canada's burdened healthcare system and necessary resource-utilization efficiency.

METHODS

Patient selection

Approval was obtained from the institutional research ethics board (NSHA REB# 1027213) for this single-centre retrospective cohort study. Patients who underwent a RALPN performed by two surgeons at the QEII HSC from 01 February 2019 to 31 July 2021 (early phase of our robotics program) were identified. Subsequently, a contemporary series of OPNs and LPNs performed from 01 February 2015 until 01 February 2019 (well established PN program) by the same two surgeons before the introduction of RALPN was identified. The QEII HSC group attempted to transition fully to RALPN as soon as the da Vinci robot became available, therefore very few OPNs (15) or LPNs (4) were performed after 01 February 2019. One patient was removed from the OPN group as they had a total tumour per renal unit count of greater than or equal to five for both kidneys making it hard to report reliable tumour characteristics and RENAL scores. No other patients were excluded from the study.

Data collection

Baseline characteristics that were captured included age at time of procedure, sex, height, weight, BMI, radiologic size of the tumour, tumour laterality, number of tumours per renal unit, and RENAL nephrometry score (obtained by analyzing radiologic images of tumour). The tumour with the highest RENAL score was used for data analysis in patients who had multiple tumours. Primary surgical and perioperative outcomes included EBL, WIT, operating room (OR) time, surgical procedure time, LOS, and intraoperative complications. Post-operative outcomes captured included creatinine, post-operative complications, and tumour pathology (stage, Fuhrman/ISUP grade, margins, histology, and pathologic size).

Date of post-operative creatinine (3 months post-procedure was used, if no creatinine level was available at 3 months then closest date past 3 months was used–not before 3 months), post-operative creatinine level, and post-operative complications (up to 6 months post-op including hospital stay complications, related readmissions, related ER visits, and need for ancillary procedures and testing) were all be captured and standardized using the Clavien-Dindo Grade classification.[3]

Statistical analysis

Descriptive summary statistics were used to report data for the performed RALPNs, LPNs, and OPNs. Continuous variables were compared using ANOVA and Bonferroni correction. Variables that demonstrated significant skew (greater than 1 or less than -1) and did not violate homogeneity of variances as per Levene's test were compared using the Kruskall-Wallis test and had only medians reported. Dunn's test with Bonferroni correction was used as a post-hoc test in case of significance from the Kruskal-Wallis test. Variables with significant skew that violated variance homogeneity were compared using Welch's ANOVA and had means and medians reported. Games-Howell tests with Bonferroni corrections were used as post-hoc tests in the case of significance from Welch's ANOVA. Categorical variables were compared using Fisher's

Exact tests and z-tests were used to compare groups in the case of significance. A *P*-value of <0.05 was used as the threshold for statistical significance. Stata/SE 17.0 software was used for the statistical analyses conducted in this study.[4]

RESULTS

Overall, 271 patients underwent PNs consecutively during this study period. 18 of the 271 patients had more than one tumour resected per renal unit (Table 1). 106 patients had OPNs, 83 LPNs, and 82 RALPNs. Of the 82 RALPNs, 69 (84%) of them were performed by one surgeon and 13 (16%) were performed by the other. Baseline characteristics are shown in Table 1. There were no significant differences found in sex or BMI between the three groups. Age was found to be significantly higher in the RALPN and OPN group when compared to the LPN group (*P*<0.05). Baseline creatinine was found to be greater in the OPN group when compared the LPN group (*P*<0.05). No significant difference in baseline creatinine was found between the RALPN group and both OPNs and LPNs. The OPN and RALPN group had greater RENAL score and radiologic tumour size when compared to the LPN group (*P*<0.05). No significant difference in RENAL score was found between the OPN and RALPN group (*P*=0.10). Tumours per renal unit was found to be significantly different between OPN and LPN, with OPN having the greatest number of tumours per renal unit followed by RALPN (*P*<0.05).

EBL was found to be significantly less in LPN and RALPN when compared to OPN (*P*<0.05), with a median of 250ml for OPN and 125ml and 165ml for LPN and RALPN, respectively (Table 3). WIT was found to be greater in RALPN when compared to OPN and LPN (*P*<0.05) with RALPN having a median time of 17.0 minutes compared to 14.5 and 15.0 minutes for OPN and LPN, respectively. While there was no significant difference found in total OR time between LPN and RALPN, the OPN group had a significantly greater OR time with a median time of 160 minutes compared to 146 minutes for RALPN and 150 minutes for the LPN group (*P*<0.05). Surgical procedure time was also significantly greater in the OPN group with a median of 104 minutes compared to 94 and 82 minutes for LPN and RALPN (*P*<0.05), respectively. LOS was lowest in the RALPN group with a median of 2 days compared to 3 and 4 days for the LPN and OPN group, respectively. Significant statistical differences in median LOS were found between all three groups with 2, 3, and 4 days observed for RALPN, LPN, and OPN, respectively (*P*<0.05). Postoperative creatinine was found to be significantly different between the OPN and LPN group only (*P*<0.05). Additionally, we found no statistically significant difference in use of clamp and intraoperative complications. Although there was no statistically significant difference in all Clavien-Dindo Grade complications between the three groups (*P*=0.47), there was an observed trend towards less high grade (3–5) complications in the RALPN group.

Tumour pathology outcomes are shown in Table 5. The OPN group was found to have a lower proportion of pT1a and greater proportion of pT1b disease when compared to the LPN group (*P*<0.05). Although not found to be statistically significant, RALPN had greater proportion of stage pT1b or greater disease when compared to LPN. Pathological tumour size

was found to be greater in OPN and RALPN when compared to LPN (P<0.05). Tumour size was greatest in OPN followed by RALPN, with a median pathological tumour size of 3.8cm and 3.1cm, respectively, with no significant difference between the two. There was no statistically significant difference in proportion of positive margins but there appeared to be a trend towards more positive margins in the RALPN group (P=0.36).

DISCUSSION

The current study found that RALPN demonstrated improved perioperative outcomes when compared with OPN and LPN with respect to several variables. Uniquely, these findings were identified when comparing an early-experience RALPN cohort to an established OPN and LPN cohort.

Although there is sparce data from Canadian centres, there is a growing body of literature from non-Canadian centres looking at RALPN outcomes compared to non-robotic modalities. Longer WIT and mean operative times have been associated with RALPN for SRMs and renal masses over 4cm when compared to OPN. Despite this increased WIT and operative time in the literature, a lower LOS for RALPN as well as similar intraoperative complication rates between RALPN and OPN has been observed as well as lower postoperative analgesic use associated with RALPN performed for SRMs.[5,6,8] Conversely, in one single-surgeon matched cohort Korean study comparing RALPN to OPN, they observed that while mean operative time was longer in the RALPN group, there was no significant difference in WIT and post-operative renal function when compared to the OPN group. This group also found that there was no significant difference in EBL, transfusion rate, or complications between the two groups, while LOS was once again found to be lower in the RALPN group.[7]

In our study, we identified that EBL was lower in the RALPN group when compared to OPN (P<0.05) and was comparable to the LPN group (P=0.15). These findings were in keeping with those reported by Garg et al.[8] Of interest, our data also demonstrated a significantly lower mean procedure and total OR time for RALPN in addition to LPN when compared to OPN (P<0.05), contrary to what is found in the literature as many previous studies have reported longer mean operative time with RALPN when compared to other modalities.[5-8] One possible reason for the shorter procedure and OR time with RALPN could be that there was greater staff surgeon involvement in RALPNs during the early phase of our robotics program as opposed to the well-established LPN and OPN program where resident operative experience and training was prioritized more. Additionally, with the robotic approach there was less dissection required around the hilum and less instruments used during the procedure. Another significant finding from our study was a lower median LOS (P<0.05) associated with RALPN (2 days) versus LPN (3 days) and OPN (4 days). Our findings were in keeping with numerous other studies in the literature that observed shorter LOS for RALPN for cT1 and cT2 renal masses when compared to non-robotic modalities.[5-9] This was an important finding from our study as RALPN was associated with lower LOS and similar operating room time and procedure time as LPN, while

RENAL score for RALPN was greater than that of the LPN group (<0.05) and not significantly different than the OPN group (*P*=0.10).

There was no significant difference observed in the number of intraoperative complications or Clavien-Dindo Grade between the three groups. These findings were similar to studies already in the literature demonstrating similar intraoperative and postoperative complication rates.[5-8] Although not statistically significant, we did observe the RALPN group to have a lower number of intraoperative complications and no Clavien-Dindo Grade IV–V complications when compared to OPN and LPN. Interestingly, we found WIT to be significantly longer in the RALPN group compared to the other two groups, with a median of 17 minutes for RALPN versus 14.5 and 15 minutes for OPN and LPN, respectively. Lee et al. reported similar findings, whereas Oh et al. did not find any significant difference with respect to WIT between RALPN and OPN.[5-7] A relevant point that may explain the difference in WIT between our groups is that at the QEII HSC, the early unclamping technique was used for most OPN and LPN but not in RALPN. Another interesting finding from our study, albeit not statistically significant (*P*=0.36), was that RALPN had a higher proportion of positive margins (7.4%) compared to OPN (1.9%) and LPN (2.4%). We hypothesize that the observed increase in positive margins could have been part of the learning curve of performing RALPN. This could also be due to more enucleations performed in RALPN or tumour ruptures from forcing tumours during extraction within the EndoCatch bag.

An important strength of this study was that we used data from our local institution and compared RALPN, LPN, and OPN separately as opposed to grouping LPN and OPN together. Many studies in the literature comparing RALPN to other modalities often group LPN and OPN together or compare RALPN to OPN only. As LPN was introduced as a minimally invasive replacement to open procedures when feasible, we aimed to compare RALPN to not only OPN but also the non-robotic laparoscopic approach. It is also worth noting that the RALPN group in our study included all patients that underwent PN from the inception of the robotics program at our institution (early phase) and that none of these cases were converted to open procedures. Apart from WIT, which is still well below 20 minutes, the findings from our series show that perioperative outcomes improved with the introduction of RALPN for the treatment of renal masses.

Limitations

One limitation of this study was that surgeon experience with time was not taken into consideration. For example, operative outcomes may improve over time as the surgeon gains experience with increasing volume of procedures using a certain modality. Although this was a two-surgeon study, RALPNs were not equally divided between the two operators, partly due to difference in stage of career. However, both were experienced open and laparoscopic surgeons at the time of RALPN introduction at our centre. Though we examined perioperative outcomes during only the initial phase of the robotics program for PN at this site, looking at perioperative

outcomes longitudinally in future studies may give insight into the potential improvements in outcomes that occur with experience using the robotic platform.

Another limitation of this study was that there may have been an inherent selection bias for the RALPN group. Our group attempted to fully transition to RALPN as soon as the robot was available at our institution, resulting in greater than 90% of PNs performed after the arrival of the robot to be performed robotically. Even though 15 OPNs were performed after the robot was introduced and RENAL scores were not significantly different between OPN and RALPN, it is still possible that some borderline difficult tumours may have been treated with radical nephrectomy as opposed to OPN during the robotics era, leading to possible selection bias.

CONCLUSIONS

We found that although patients undergoing RALPN had slightly longer WIT, they had similar rates of intraoperative and postoperative complications; required less total OR time, had shorter procedure times, and had lower LOS when compared to LPN and OPN despite greater RENAL score compared to LPN and no significant difference in RENAL score compared to OPN during the early phase of our robotics program.

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FIGURES AND TABLES

Table 1. Baseline characteristics					
	Overall	**Open**	**Laparoscopic**	**Robotic**	**p**
Number of patients	271	106	83	82	
Sex, n (%) Male Female	 171 (63.1) 100 (36.9)	 71 (67.0) 35 (33.0)	 50 (60.2) 33 (39.8)	 50 (61.0) 32 (39.0)	0.55
Age, years, mean (range)	55.32 (24.0–75.0)	55.80 (26.0–75.0)	52.10 (30.0–74.0)	57.98 (24.0–75.0)	<0.05
BMI, kg/m^2, mean (range)	30.55 (16.3–54.7)	30.49 (16.3–54.7)	30.35 (19.0–50.4)	30.83 (20.9–52.9)	0.88
Baseline creatinine, µmol/L Mean (range) Median	 81.08 (42–239) 76	 87.22 (48–221) 78	 75.54 (42–105) 74	 78.76 (42–239) 75	<0.05
Tumor number per renal unit, n (%) 1 ≥2	 253 (93.4) 18 (6.6)	 93 (87.7) 13 (12.3)	 83 (100) 0 (0)	 77 (93.9) 5 (6.1)	<0.05
Radiologic tumor size, cm Mean (range) Median	 3.53 (0.7–13.2) 3.2	 4.09 (1.1–13.2) 3.7	 2.79 (1.1–6.5) 2.8	 3.58 (0.7–8.9) 3.2	<0.05
RENAL nephrometry score Mean (range) Median	 7.02 (4–10) 7	 7.55 (4–10) 8	 6.32 (4–10) 6	 7.05 (4–10) 7	<0.05

Table 2. Perioperative outcomes					
	Overall	**Open**	**Laparoscopic**	**Robotic**	**p**
Estimated blood loss, mL, median (range)	200 (0–2500)	250 (10–2500)	125 (0–2000)	165 (0–1300)	<0.05
Clamp, n (%)					0.48
Yes	232 (86.9)	95 (89.6)	66 (83.5)	71 (86.6)	
No	35 (13.1)	11 (10.4)	13 (16.5)	11 (13.4)	
Warm ischemia time, minutes					<0.05
Mean (range)	16.72 (7.0–49.0)	15.76 (7.0–32.0)	15.88 (7.0–35.0)	18.80 (7.0–49.0)	
Median	15.0	14.5	15.0	17.0	
Operating room time, minutes					<0.05
Mean (range)	159.17 (87–324)	170.33 (104–324)	152.93 (94–221)	151.73 (87–279)	
Median	151.5	160	150	146	
Procedure time, minutes					<0.05
Mean (range)	99.93 (24.0–231.0)	109.99 (40.0–231.0)	97.45 (41.0–179.0)	89.43 (24.0–225.0)	
Median	97	104	96	82	
Intraoperative complications, n (%)					0.92
Yes	9 (3.3)	4 (3.8)	3 (3.6)	2 (2.4)	
No	262 (96.7)	102 (96.2)	80 (96.4)	80 (97.6)	
Length of stay, days, median (range)	4.0 (1–25)	4.0 (2–25)	3.0 (2–8)	2.0 (1–14)	<0.05
Postoperative creatinine, µmol/L					<0.05
Mean (range)	92.83 (46–268)	100.24 (49–268)	83.65 (46–125)	91.29 (47–251)	
Median	87	89	81	87	
Clavien-Dindo grade, n (%)					0.47
0	178 (65.9)	64 (59.8)	58 (69.9)	56 (70.0)	
I–II	64 (23.7)	28 (26.2)	19 (22.9)	17 (21.3)	
IIIa–IIIb	26 (9.6)	14 (13.1)	5 (6.0)	7 (8.8)	
IV–V	2 (0.7)	1 (0.9)	1 (1.2)	0 (0)	

Table 3. Tumor pathology					
	Overall	**Open**	**Laparoscopic**	**Robotic**	**p**
Stage, n (%)					<0.05
pT1a	158 (67.5)	50 (53.2)	61 (84.7)	47 (69.1)	
pT1b	49 (20.9)	27 (28.7)	8 (11.1)	14 (20.6)	
pT2	5 (2.1)	3 (3.2)	0 (0)	2 (2.9)	
pT3	20 (8.6)	12 (12.8)	3 (4.2)	5 (7.4)	
pT4	2 (0.8)	2 (2.1)	0 (0)	0 (0)	
Fuhrman/ISUP grade, n (%)	89 (40.6)	25 (28.7)	34 (49.3)	30 (47.6)	<0.05
1–2	130 (59.4)	62 (71.3)	35 (50.7)	33 (52.4)	
3–4					
Margin, n (%)					0.36
Positive	10 (3.8)	2 (1.9)	2 (2.4)	6 (7.4)	
Negative	249 (93.6)	99 (96.1)	77 (93.9)	73 (90.1)	
Indeterminate	7 (2.6)	2 (1.9)	3 (3.7)	2 (2.5)	
Histology, n (%)					0.34
Malignant	235 (86.7)	96 (90.6)	70 (84.3)	69 (84.2)	
Benign	36 (13.3)	10 (9.4)	13 (15.7)	13 (15.8)	
Pathological tumor size, cm					<0.05
Mean (range)	3.46 (0.8–15.5)	4.09 (1.3–15.5)	2.66 (0.8–7)	3.48 (1.4–8.2)	
Median	3	3.8	2.55	3.1	