Comparison of robotic and open partial nephrectomy: Single-surgeon matched cohort study

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Abstract

Introduction: We present comparative outcomes among matched patients who underwent robotic partial nephrectomy (RPN) or open partial nephrectomy (OPN) by a single surgeon at a single institution.

Methods: We reviewed the medical records of 200 patients who underwent RPN (n = 100) or OPN (n = 100) between May 2003 and May 2013. The patients who underwent RPN were matched for age, gender, body mass index (BMI), American Society of Anesthesiologists (ASA) score, as well as tumour size, side and location. Perioperative outcomes were compared.

Results: There was no significant difference between the 2 cohorts with respect to patient age, BMI, ASA score, preoperative glomerular filtration rate, tumour size and the R.E.N.A.L. nephrometry score. The mean operative time was longer in the RPN group, but there were no significant differences with respect to warm ischemic time and postoperative renal function. The length of hospitalization and use of postoperative analgesics (ketoprofen) were more favourable in the RPN cohort. There was no significant difference in the mean estimated blood loss, transfusion rate, or complications between the cohorts.

Conclusions: Considering the perioperative and postoperative parameters, RPN is a viable option as a nephron-sparing surgical procedure for small renal masses that yields outcomes comparable to those achieved with OPN. Despite matched cohort analysis among patients who underwent PN by a single surgeon, there may be inherent selection bias; therefore future prospective trials are needed.

Introduction

Radical nephrectomy (RN) has been considered the gold standard for managing small renal masses (SRMs).[1] With the improvement of surgical techniques, partial nephrectomy (PN) has now become the norm for the management of renal tumours smaller than 4 cm (T1a).[2,3] A recent series showed a similarity between PN and RN for oncological control and demonstrated the superiority of PN for preserving renal function, preventing chronic renal disease along with associated cardiovascular morbidity and mortality, and improving overall survival rates.[4,5]

Over the last decade, laparoscopic surgery has become the common technique for many urologic procedures. The main advantages of minimally invasive surgery are lower blood loss and transfusion rates, reduced postoperative pain and scarring, faster recovery from surgery, and a shorter length of hospitalization. In contrast, laparoscopic partial nephrectomy (LPN) is considered a technically challenging procedure that requires considerable skill and expertise, such as intracorporeal suturing, combined with the necessity to minimize ischemic times.[6]

Robot-assisted partial nephrectomy (RPN) may help overcome the technical challenges of LPN and offers an easier transition to minimally invasive PN.[7] RPN is suitable for intracorporeal suturing with the use of an endo-wrist instrument.[8] To date, numerous preliminary studies on RPN have shown that this technique is comparable to LPN.[9] Although one recent report on the outcomes of RPN compared with OPN has been promising,[10] there are almost no studies that have compared RPN with OPN. We present a single-surgeon comparative study of OPN and RPN in matched patients.

Methods

Between May 2003 and May 2013, a retrospective cohort study was performed to evaluate perioperative outcomes among patients who underwent RPN and to compare these results with those of a matched cohort of patients who were selected among the OPN database. This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital.

A total of 100 consecutive RPN patients were matched with 100 OPN patients who were similar with respect to age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, laterality of the tumour, tumour size, tumour location and preoperative glomerular filtration rate (GFR). We also matched the cohorts according to the R.E.N.A.L. nephrometry scoring system.[11] We excluded patients with a single kidney, bilateral renal masses, von Hippel-Lindau syndrome or OPN under hypothermia with cold ischemia.

We defined exophytic tumours as those that covered more than 60% off the natural kidney surface. Endophytic tumours covered less than 40% of the surface of the kidney, and mesophytic tumours covered 40% to 60% of the natural border of the kidney. Hilar lesions were defined by localization within 5 mm of the renal hilar structures regardless of their surface characteristics.[12] The total R.E.N.A.L. nephrometry score was categorized as low (4–6 points), moderate (7–9), or high (10–12) complexity.[11] The specimens obtained from PNs were evaluated for pathologic tumour size, histologic subtype, Fuhrman nuclear grade, and pathologic tumour-node-metastasis stage according to the 7th edition of the American Joint Committee on Cancer Cancer (AJCC) Staging Manual.[13]

Follow-up abdominal imaging studies, such as computed tomography (CT), were performed every 6 to 12 months after non-sparing surgery to assess recurrence. Functional renal outcomes were assessed by comparing preoperative and postoperative GFR and creatinine levels. A 3-arm technique was used during RPN, and 2 additional assistant ports were placed. Port location was tailored to the location of the mass and renal hilum. All of the hilar control procedures during RPN and OPN were performed under warm ischemia. In cases of RPN, hilar control was achieved by clamping the renal artery. In some hilar tumours, the renal veins were also controlled with bulldog clamps. Similar hilar control was achieved in OPN cases. Most renal reconstruction during RPN consisted of a 2-layer repair. The first part of the repair involved intraparenchymal suturing to close the collecting system and to achieve hemostasis with the use of continuous 3-0 polyglactin and Lapra-Tys sutures (Ethicon, Somerville, NJ). The second part of the repair involved parenchymal suturing with the use of 1-0 polyglactin and a sliding-knot technique. When the expected ischemia time was ≥30 minutes, early unclamping was performed after intraparenchymal suturing.[14] Supplementary ties over a Surgicel (Ethicon, Somerville, NJ) or TachoComb (NYCOMED, Linz, Austria) bolster were created using remnant 1-0 sutures. A topical hemostatic agent, Tissel (Baxter Corp, Deerfield, IL), was applied over the bolster and at the base of the resection bed. Similar renal reconstruction was performed in OPN cases.

All data analyses were performed using the Statistical Package for the Social Sciences 17.0 software (SPSS Inc, Chicago, IL). We tested the distribution of clinicopathologic parameters using chi-square and Student's t tests. We compared the complications and renal functional outcomes after nephrectomies according to surgical methods. Complications were stratified by Clavein Dindo classficiation.[15] All p values were two-sided and <0.05 was considered significant.

Results

A total of 100 consecutive patients who underwent RPN were reviewed and matched to a contemporary cohort of 100 patients who underwent OPN by the same surgeon. Demographic data are summarized in Table 1. There was no significant difference between the 2 cohorts with respect to age, gender, BMI, ASA score, tumour laterality, tumour size, tumour location, R.E.N.A.L. nephrometry score or preoperative eGFR.

Table 2 shows the perioperative outcomes for both groups. The mean operative time was longer in the RPN group (182 vs. 138 min, $p < 0.001$), but the mean warm ischemia time (WIT) was similar between the RPN and OPN cohorts (21.86 vs. 21.18 min, $p = 0.734$). There were no significant differences between the groups (RPN vs. OPN) in terms of the estimated blood loss (EBL) (212 vs. 230 mL, $p = 0.545$) and transfusion rate (6.0% vs. 4.0%, $p = 0.661$).

Table 1. Demographic characteristics of study patients

Characteristics	OPN (n=100)	RPN (n=100)	*p* value
Age, years	54.59 ± 13.40	54.27 ± 11.52	0.896
Sex			0.835
Male	69 (69.0%)	70 (70.0%)	
Female	31 (31.0%)	30 (30.0%)	
Body mass index, kg/m^2	25.14 ± 2.73	25.48 ± 3.47	0.161
Mean ASA score	1.6	1.5	0.280
Tumour laterality			0.847
Right	52 (52.0%)	46 (46.0%)	
Left	48 (48.0%)	54 (54.0%)	
Tumour size, cm (range)	2.59 ± 1.35 (0.80-6.20)	2.52 ± 1.26 (0.90-6.00)	0.763
Tumour location			0.437
Exophytic	26 (26.0%)	31 (31.0%)	
Mesophytic	23 (23.0%)	27 (27.0%)	
Endophytic	30 (30.0%)	27 (27.0%)	
Hilar	21 (21.0%)	15 (15.0%)	
Median R.E.N.A.L. nephrometry score (IQR)	7 (6-9)	7 (6-9)	0.883
Low group	39 (39.0)	40 (40.0)	
Moderate group	47 (47.0)	48 (48.0)	
High group	14 (14.0)	12 (12.0)	
Preopertive Cr, mg/dL	1.11 ± 0.37	1.04 ± 0.22	0.085
Preopertive GFR, mL/min	76.21 ± 20.95	78.18 ± 18.42	0.530

OPN: open partial nephrectomy; RPN: robotic partial nephrectomy; ASA: American Society of Anesthesiologists; Cr: creatinine; GFR: glomerular filtration rate; IQR: interquartile range. The total RENAL nephrometry score was categorized as low (4–6 points), moderate (7–9), or high (10–12) complexity.

Table 2. Perioperative outcomes

Characteristics	OPN (n=100)	RPN (n=100)	*p* value
Operative time (min)	138.79 ± 40.29	182.89 ± 83.98	<0.001
Warm ischemic time (min) (range)	21.18 ± 11.29 (6-60)	21.86 ± 9.25 (6-55)	0.734
EBL (mL)	230.74 ± 159.33	212.04 ± 160.76	0.545
Transfusion (%)	6 (6.0)	4 (4.0)	0.661
Hospital stay (d)	9.26 ± 3.22	5.41 ± 1.84	<0.001
Postoperative analgesics (ampule)	0.9 ± 0.23	0.2 ± 0.11	<0.001
Intraoperative complications (%)	3 (3.0)	4 (4.0)	0.714
Postoperative complications (%)	8 (8.0)	10 (10.0)	0.440
Prolonged ileus	2 (2.0)	3 (3.0)	
Wound problem	0 (0.0)	2 (2.0)	
Urine leakage necessary stent insertion	2 (2.0)	0 (0.0)	
Prolonged bleeding	3 (3.0)	1 (1.0)	
Prolonged hematuria	1 (1.0)	4 (4.0)	

OPN: open partial nephrectomy; RPN: robotic partial nephrectomy; EBL: estimated blood loss.

Table 3. Pathological outcomes

Characteristics	OPN (n=100)	RPN (n=100)	*p* value
Pathologic diagnosis (%)			0.886
Clear cell RCC	84 (84.0)	81 (81.0)	
Papillary RCC	6 (6.0)	7 (7.0)	
Chromophobe RCC	4 (4.0)	6 (6.0)	
Angiomyolipoma	2 (2.0)	3 (3.0)	
Oncocytoma	4 (4.0)	3 (3.0)	
Pathologic stage (%)			0.197
pT1a/pT1b	87 (87.0)/8 (8.0)	90 (90.0)/8 (8.0)	
pT2/pT3a	1 (1.0)/5 (5.0)	0 (0.0)/2 (2.0)	
Fuhrman nuclear grade			
1/2/3/4	2/50/43/5	0/49/50/1	0.500
Resection margin positive (%)	1 (1.0)	0 (0.0)	0.315

OPN: open partial nephrectomy; RPN: robotic partial nephrectomy; RCC: renal cell carcinoma.

As expected, the length of hospitalization (5.4 vs. 9.3 days, $p < 0.001$) and use of postoperative analgesics (ketoprofen, 0.2 vs. 0.9 ampules, $p < 0.001$) were more favourable in the RPN cohort.

Intraoperative adverse events occurred in 3 OPN patients (3.0%) and 4 RPN patients (4.0%) ($p = 0.714$). Complications in the OPN group included 3 cases of pleural injury. Complications in the RPN groups included 2 colon, 1 spleen and 1 renal vein injury. The rate of postoperative complications was 8.0% in the OPN group and 10.0% in the RPN group ($p = 0.440$). Most complications were classified as Clavien grade I and II. Clavien grade III complications occurred in 3 patients in the OPN group (urine leakage necessitating ureteral stents, prolonged bleeding necessitating angioembolization) and 2 patients in the RPN group (angioembolization for prolonged bleeding). Most complications in the robotic group occurred among the first 20 cases.

In the OPN cohort, pathologic findings demonstrated AJCC stage T1a in 87 (87.0%) patients and stage T1b in 8 (8.0%) patients. In the RPN cohort, pathology was classified as AJCC stage T1a in 90 (90.0%) patients and stage T1b in 8 (8.0%) patients. The histologic type, pathologic stage, and Fuhrman nuclear grade were not significantly different between the groups (Table 3). The number of patients with positive surgical margins was 0 for the RPN group and 1 for the OPN group ($p = 0.500$).

There was no significant difference in postoperative GFR (71.49 vs. 72.29 mL/min, $p = 0.147$) or percent change in GFR (-6.19% vs. -7.53%, $p = 0.418$) between the OPN and RPN cohorts, respectively (Table 4). Postoperative serum creatinine was also similar between OPN and RPN cohorts (1.14 vs. 1.09 mg/dL, $p = 0.085$). Likewise, there was no significant difference in percent change in creatinine between the OPN and RPN cohorts (2.70% vs. 4.81%, $p = 0.067$).

Discussion

PN has become the standard procedure for removing SRMs.[3,16] The 10-year oncologic control rate in patients undergoing PN has been comparable to that of those undergoing RN.[16] Furthermore, for large tumours >4 cm, elective PN should be performed at high-volume centres because

Table 4. Postoperative renal functional outcomes

Characteristics	OPN (n=100)	RPN (n=100)	*p* value
Mean preoperative serum Cr (mg/dL) ± SD	1.11 ± 0.32	1.04 ± 0.12	0.085
Mean postoperative serum Cr (mg/dL) at 6 months ± SD	1.14 ± 0.76	1.09 ± 0.52	0.157
Mean percentage change of serum Cr (%) ± SD	2.70 ± 1.21	4.81 ± 1.98	0.067
Mean preoperative GFR (mL/min/1.73m^2) ± SD	76.21 ± 25.83	78.18 ± 21.72	0.530
Mean postoperative GFR (mL/min/1.73m^2) at 6 months ± SD	71.49 ± 31.15	72.29 ± 29.46	0.147
Mean percentage change GFR (%) ± SD	-6.19 ± 7.32	-7.53 ± 4.28	0.418

OPN: open partial nephrectomy; RPN: robotic partial nephrectomy; Cr: creatinine; SD: standard deviation; GFR: glomerular filtration rate.

the oncologic results achieved are equivalent to those seen with RN, with the added advantage of renal functional preservation.[17,18]

Traditionally, open method was standard surgical approach for PN; however, OPN is associated with some morbidity and prolonged convalescence.[19] Therefore, LPN was developed and refined to minimize the morbidity associated with OPN.[20,21] Lane and Gill[22] assessed the 5-year oncologic and renal functional outcomes in 56 patients. They reported no cancer-specific death, and no patients developed postoperative chronic renal insufficiency. Recent large LPN series were comparable to those of open surgery.[20,22,23] Gill and colleagues[20] reported equivalent 3-year cancer-specific survival rates of 99.3% and 99.2%, respectively, compared with the early postoperative outcomes of 771 LPN and 1028 OPN cases. LPN offers comparable disease control but with less pain, superior cosmesis, and a shortened hospital stay. However, LPN is technically more demanding and has a prohibitive learning curve.[24] Because in situ renal hypothermia during LPN has been largely unsuccessful, the kidney is placed at considerable risk for post-ischemic injury if WIT takes longer than 30 minutes.[25,26] Even in expert hands, the mean WIT during LPN approaches or exceeds this threshold.[20] In our LPN series, the mean WIT was close to 30 minutes and the unfavourable complication rate was higher than among the OPN or RPN series. LPN was more difficult in large-sized and high complex tumours; therefore, LPN candidate patients were recommended to the RPN series.

RPN may help overcome the technical difficulties of LPN and offers an easier transition to minimally invasive PN.[7] The articulating wrist-like action achieved using the da Vinci robot and 3-dimensional visualization would offer potential advantages during a PN. In particular, tumour excision and intracorporeal suture repair may be facilitated. The ease of tumour excision and suture repair may translate into shorter WIT and a reduction in uncontrolled bleeding after unclamping.[27] Rogers and colleagues[28] reported that robotic assistance could be advantageous for renal hilar tumours and demonstrated that RPN could be both safe and effective in complex renal masses. Benway and colleagues[29] reported that the WIT in RPN was shorter than in LPN and involved less EBL compared to a series that examined 129 RPN and 118 LPN patients. In our series, the mean WIT of RPNs was about 20 minutes; there was no positive surgical margin and no significant decrease in renal function. This evidence suggests that RPN was safe and effective for PN.

Although several studies compared the clinical outcomes between RPN and LPN, few reports have compared OPN and RPN. One retrospective study recently compared 69 RPNs with 234 OPNs.[10] The findings showed that the mean operation time and WIT were longer in the RPN group, but there were no significant differences in the postoperative GFR. However, this series had considerable selection bias. To our knowledge, our matched cohort study represents the only single-surgeon series in which RPN outcomes were compared with a control group of OPN patients operated on by the same surgeon.

The results of our matched cohort study support the role of RPN in the management of small, radiographically enhancing renal masses. Both cohorts demonstrated excellent renal functional and perioperative outcomes. In a PN series, WIT is usually accepted as the crucial parameter for evaluating reasonable operative outcomes.[9] After matching the renal tumour profile (size, location and laterality), patient age and ASA score, WIT was similar between OPN and RPN (21.18 vs. 21.86 min, $p = 0.734$), in contrast to a previous study.[10] Moreover, hospital stay and postoperative pain (as represented by the dosage of analgesics) were shorter in the RPN cohort than in the OPN cohort. This identifies RPN as a new alternative to OPN.

The primary limitation of our study was its retrospective nature. Selection bias and patient confounders were minimized by matching the RPN cohort to demographically similar OPN patients. Surgical confounders were minimized by using the outcomes of a single surgeon. Further randomized, controlled, prospective trials are needed to confirm our results.

Conclusions

The outcomes of this study support RPN as an effective and safe alternative to OPN. With the improvements in related technology, RPN might be easier and more effective than renal surgery. RPN has become a popular procedure because of its short learning curve and the translational capacity of the robotic operating platform coupled with its superior optics and flexibility. Further prospective comparative studies are necessary to confirm these encouraging findings.

Competing interests: Dr. Oh, Dr. Byun, Dr. Hong, Dr. Jeong and Dr. Lee all declare no competing financial or personal interests.

This paper has been peer-reviewed.

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