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ORIGINAL ARTICLE

Robotic partial nephrectomy: a multi-institutional analysis

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Abstract Laparoscopic partial nephrectomy for kidney tumors has demonstrated durable oncologic and functional outcomes. The feasibility of robotic partial nephrectomy (RPN) has been demonstrated in several small, single-institution studies. We performed a large, multi-institutional analysis to determine early oncologic results and perioperative outcomes after RPN. Between October, 2002 and September, 2007, 148 patients underwent RPN at six different centers by nine different primary surgeons for localized renal tumors. Medical and operative records were reviewed for clinical characteristics, pathologic findings, and follow-up information. A total of 148 patients underwent RPN. Mean tumor size was 2.8 cm. Renal hilar clamping was utilized in 120 patients, with a mean warm ischemia time of 27.8 min. Positive surgical margins were identified in six patients (4%), of which two had cautery artifact obscuring the margin after off-clamp cautery excision and one underwent completion radical nephrectomy with no evidence of cancer. There is no evidence of tumor recurrence at mean follow-up of 7.2 months (range 2–54 months) overall, and mean follow-up of 18 months (range 12–23 months) for patients with positive surgical margin. Complications occurred in nine patients (6.1%), including hematoma requiring drainage ($n = 1$), prolonged ileus ($n = 3$), pulmonary embolus ($n = 2$), prolonged urine leak ($n = 2$), and rhabdomyolysis ($n = 1$). Two patients underwent open conversion for failure to progress, one patient with morbid obesity and one patient with adhesions from prior ureterolithotomy. Mean hospital stay was 1.9 days. In this multi-institutional series of surgeons beginning their initial experience in RPN, the procedure is a feasible option for minimally invasive, nephron-sparing surgery, with immediate oncologic results and perioperative outcomes comparable with more mature laparoscopic series.

Keywords Kidney cancer · Laparoscopy · Partial nephrectomy · Robotics · Technique

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Introduction

Nephron-sparing procedures are increasingly seen as advantageous compared to radical nephrectomy for small renal neoplasms. With the advent of minimally invasive partial nephrectomy, patients may maintain the oncological and functional benefits of nephron-sparing surgery [1–3] while maintaining the benefits of improved convalescence after minimally invasive surgery. Laparoscopic partial nephrectomy (LPN), however, is a technically challenging procedure. Advanced laparoscopic skills are required to achieve precise tumor resection and renal reconstruction during LPN while minimizing warm ischemia times. The feasibility of robotic partial nephrectomy (RPN) has been

demonstrated in several small, single-institution studies [4–8]. We report combined initial early oncologic results and perioperative outcomes with RPN from a multi-institutional group of urologists beginning their initial experience with RPN.

Methods

Between October 2002 and September 2007, 148 patients underwent RPN for localized renal tumors at six different academic and private hospital centers by nine different primary surgeons who had each performed at least five cases. Medical and operative records were retrospectively reviewed for clinical characteristics, pathologic findings, and follow-up information in order to determine early oncologic results and perioperative outcomes after RPN.

Selection for a robotic approach was based on the presence of a renal tumor suspicious for malignancy on preoperative imaging, the ability of the patient to undergo minimally invasive and nephron-sparing surgery, robot availability, and both surgeon and, patient preference.

Surgical technique varied between centers, according to type of robot (standard or "S") and surgeon preferences such as port location and hemostatic agents used. Several centers in our study have already described their respective techniques [5, 6, 8–10]. No patients had a solitary kidney. A transperitoneal approach was used. Hilar clamping with bulldog clamps was used to achieve warm ischemia.

Results

A total of 148 patients (mean age 60 years, range 25–83 years) underwent RPN for kidney tumors. Table 1 lists patient characteristics, perioperative outcomes, and early follow-up. Mean tumor size was 2.8 cm, mean warm ischemia time was 27.8 min, mean operating time was 197 min, mean blood loss was 183 ml, and mean hospital stay was 1.9 days. Histopathology confirmed renal cell carcinoma histologic subtypes in 109 patients (74%) and benign histologies in 39 patients (26%). Positive surgical margins occurred in six patients (4%). Two positive margins occurred in patients who underwent off-clamp tumor excision with cautery artifact obscuring the true surgical margin. One patient with a positive margin elected to undergo completion radical nephrectomy, with a final pathology showing no evidence of residual tumor. There is no evidence of tumor recurrence at a mean follow-up of 7.2 months (range 2–54 months) overall, and a mean follow-up of 18 months (range 12–23 months) for patients with a positive surgical margin. There was no statistically significant difference in outcomes among the different centers in our study.

Table 1 Demographics and perioperative outcomes of 148 patients undergoing robotic partial nephrectomy from October 2002 to September 2007

RPNs, *n*	148	
Sex, *n* (%)		
Male	89	(60.1)
Female	59	(39.9)
Mean patient age, years (range)	60	(25–83)
Mean tumor size, cm (range)	2.8	(0.8–7.5)
Side, *n* (%)		
Right	80	(54.1)
Left	68	(45.9)
Mean OR time, min (range)	197	(63–392)
Mean warm ischemia time, min (range)	27.8	(12–60)
Mean EBL, ml (range)	183	(15–1,000)
Length of stay, days (range)	1.9	(1–7)
Pathologic stage[a], *n* (%)		
pT1a	87	(79.8)
pT1b	15	(13.8)
pT2	3	(2.7)
pT3a	4	(3.7)
Histopathology, *n* (%)		
Clear cell RCC	44	(29.7)
Papillary RCC	21	(14.2)
Chromophobe RCC	2	(0.1)
Unclassified RCC	42	(28.4)
Oncocytoma	14	(9.5)
Angiomyolipoma	9	(6.1)
Other benign histologies	16	(10.8)
Positive surgical margins, *n* (%)	6	(4.0)
Complications, *n* (%)	9	(6.1)
Mean follow-up, months (range)	7.2	(2–54)

[a] Pathologic stage for 109 patients undergoing partial nephrectomy for malignancy

Postoperative complications occurred in nine patients (6.1%) including hematoma requiring drainage ($n = 1$), prolonged ileus ($n = 3$), pulmonary embolus ($n = 2$), prolonged urine leak ($n = 2$), and rhabdomyolysis ($n = 1$). Two patients underwent open conversion for failure to progress, one patient with morbid obesity and one patient with adhesions from prior ureterolithotomy. No patients exhibited a statistically significant change in serum creatinine or estimated glomerular filtration rate (mean preoperative creatinine 1.0 mg/dl, range 0.7–1.6 mg/dl, mean change in creatinine at discharge 0.1 mg/dl, range −0.4 to 0.5 mg/dl). Mean hospital stay was 1.4 days in patients without complications and 5.3 days in patients with complications. A total of four patients (2.7%) underwent blood transfusion.

Discussion

Laparoscopic partial nephrectomy has demonstrated excellent long-term renal functional and oncologic outcomes [1–3], but requires advanced skills in laparoscopy to accomplish tasks of tumor resection and renal reconstruction while minimizing warm ischemia times. Robotic assistance offers potential benefits, including magnified three-dimensional visualization and articulating robotic instruments, that may facilitate precise tumor resection and renal reconstruction during partial nephrectomy. The feasibility of RPN has been described in several small reports from single institutions [4–8]. Our multi-institutional experience confirms the safety and feasibility of RPN in select patients with renal tumors.

It is critical to emphasize that this series represents the initial experience with RPN from these institutions, and it is likely that the results are reflective of an ongoing learning curve, since the overall numbers are low for each individual center. It is expected that, over time, lower warm ischemic times, shorter operative times, and more favorable morbidity profiles will be achieved. Despite the learning curve, the immediate oncologic results and perioperative outcomes approach those of more mature laparoscopic series. However, it is difficult to compare the results herein to mature laparoscopic and open partial nephrectomy series, since this series represents the pilot approach at these institutions. As experience becomes more mature, formal comparisons will be more valid.

Potential limitations of our study include the variability in technique among the different surgeons in the study, such as type of robot, port location, robotic instruments, and hemostatic agents used. This variability in technique among the different surgeons, however, demonstrates the versatility of robotic assistance according to different surgeon preferences. Other limitations are related to the retrospective nature of this series—the tumors were not sequentially treated, the clinical care pathways were not choreographed, and there is likely undetected selection bias in the cases.

Potential advantages of robotic assistance for partial nephrectomy include improved visualization and precision for tumor excision and renal reconstruction within time constraints of warm ischemia. Potential disadvantages of RPN include the cost and the need for an experienced bedside assistant. Cost is always a controversial topic with robotic series, but it would be fair to mention that the cost of the robot may be prohibitive.

Overall, this series is not meant to compare the outcomes of robotic, laparoscopic, and open partial nephrectomy, and such a comparison would be needed to assess the superiority of any one technique. The robotic approach to partial nephrectomy seems to have some reproducibility in this multi-institutional series, and further investigation should be performed to assess its role in nephron-sparing surgery.

Conclusions

We report a large, multi-institutional series of RPN for renal tumors, confirming safety and feasibility reported in previous small, single-institution studies. Although we report the initial experience in RPN at each center, immediate oncologic results and perioperative outcomes approached those of more mature laparoscopic series. Robotic assistance may facilitate the technical challenges of precise tumor resection and renal reconstruction within acceptable warm ischemia times. Long-term outcomes are needed to establish the role of RPN in nephron-sparing surgery.

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