ORIGINAL ARTICLE

Robot-assisted versus standard laparoscopic partial nephrectomy: comparison of perioperative outcomes from a single institution

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Objective To evaluate the perioperative outcomes of robot-assisted laparoscopic partial nephrectomy and standard laparoscopic partial nephrectomy in a teaching hospital.

Design Retrospective study.

Setting Division of Urology, Department of Surgery, Queen Mary and Tung Wah hospitals, Hong Kong.

Patients The first 10 consecutive patients who had robot-assisted laparoscopic partial nephrectomy for renal tumours between January 2008 and September 2009 with prospective data collection were evaluated. Their outcomes were compared with the last 10 consecutive patients in our database, who had standard laparoscopic partial nephrectomy between November 2004 and October 2007.

Main outcome measures Demographics, tumour characteristics, perioperative outcomes, renal function, and pathological outcomes.

Results There were no differences between the groups with regard to age (63 vs 56 years; P=0.313) and tumour size (2.7 vs 2.8 cm; P=0.895). No significant difference was found between the two groups with respect to the operating room time (376 vs 361 min; P=0.722), estimated blood loss (329 vs 328 mL; P=0.994), and length of hospital stay (7 vs 14 days; P=0.213). A statistically significant shorter mean warm ischaemic time for the robot-assisted group was noted (31 vs 40 minutes; P=0.032). Respective renal functional outcomes as shown by the difference between day 0 and day 60 serum creatinine levels were comparable (+10 vs +7 mmol/L; P=0.605). In both groups, there were no intra-operative complications or instances of surgical margin tumour involvement. Three patients endured postoperative complications in the standard laparoscopic group (a perinephric haematoma, urine leakage, and lymph leakage) compared with one in the robot-assisted group (a perinephric haematoma). These complications all resolved with conservative treatment.

Conclusions Robot-assisted laparoscopic partial nephrectomy is a technically feasible alternative to standard laparoscopic partial nephrectomy, and provides comparable results. Robot-assisted laparoscopic partial nephrectomy appears to offer the advantage of decreased warm ischaemic time. Longer follow-up is required to assess renal function and oncological outcomes. Further experience and randomised trials are necessary to compare robot-assisted with standard laparoscopic partial nephrectomy.

A video of robot-assisted laparoscopic partial nephrectomy is available at <www.hkmj.org>.

Key words
Kidney neoplasms; Laparoscopy; Nephrectomy; Robotics; Suture techniques

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Introduction

The incidence of diagnosed renal cancer has been increasing with the widespread use of cross-sectional abdominal imaging and the detection of incidental small renal masses. Despite recent advances in ablative therapy, surgical excision remains the cornerstone of treatment for this carcinoma.

Open partial nephrectomy is the standard for managing small renal masses, with equivalent oncological[1] and better renal functional outcomes to radical nephrectomy.[2]

機械人輔助式與標準式腹腔鏡腎部分切除術：於一所機構內進行的圍手術期結果比較

目的 探討於一所教學醫院內進行的機械人輔助式與標準式腹腔鏡腎部分切除術的圍手術期結果。

設計 回顧分析。

安排 香港瑪麗醫院及東華醫院外科泌尿科。

患者 以前瞻性方式搜集的手術結果，把2008年1月至2009年9月期間連續首10位接受機械人輔助式腹腔鏡腎部分切除術的病人，與2004年11月至2007年10月期間連續最後10位接受標準式腹腔鏡腎部分切除術進行比較。

主要結果測量 人口學、腫瘤特性、圍手術期結果、腎功能及病理結果。

結果 兩組患者的年齡（63比56歲；P=0.313）及腫瘤大小（2.7比2.8 cm；P=0.895）並無分別。此外，兩組患者的手術室時間（376比361分鐘；P=0.722）、估計失血量（329比328mL；P=0.994）及住院期（7比14天；P=0.213）亦無顯著分別。但機械人輔助式的組別有明顯較短的熱缺血時間（31比40分鐘；P=0.032）。而兩組在0天及60天的血清肝酐水平方面無分別（+10比+7 mmol/L；P=0.605），顯示他們的腎功能相若。兩組病人都沒有術中併發症及牽涉腫瘤邊緣的事件發生。標準組中有3名病人分別出現腎周圍血腫、尿漏、淋巴漏的術後併發，而機械人輔助組中只有1名病人出現腎周圍血腫。這些病人接受保守治療後均已康復。

結論 機械人輔助式腹腔鏡腎部分切除術可作為標準式腹腔鏡腎部分切除術以外的另一選擇。兩者有類似的術後結果，而機械人輔助式似乎有較短的熱缺血時間。要評估腎功能及腫瘤結果，較長的隨訪期是需要的。要比較兩種技術，需有經驗的累積及更多的隨機研究。

Development in minimally invasive surgical techniques and laparoscopic partial nephrectomy (LPN) led to improved postoperative convalescence.[3] Despite its benefit, LPN has not been widely adopted because the procedure is technically challenging with a steep learning curve. The da Vinci robot system (Intuitive Surgical, Sunnyvale [CA], US) has been applied to various urological procedures worldwide since 2000. Robot-assisted laparoscopic partial nephrectomy (RPN) has emerged as an alternative to LPN and has been explored by a number of authors.[4-12] The robotic surgical system provides a mechanical advantage for complex reconstructive surgery and benefits both the novice and experienced laparoscopic urologists in performing minimally invasive nephron-sparing surgery.[13]

We describe the first comparative study of RPN to LPN in Hong Kong, evaluating the perioperative outcomes in a teaching hospital.

Methods

Between January 2008 and September 2009, 10 consecutive patients underwent RPN in Queen Mary Hospital, which represents the first cohort having this procedure in our unit. The medical records of our last 10 consecutive patients having LPN between November 2004 and October 2007 were also reviewed. The perioperative outcomes of the groups were compared. Parameters analysed included age, American Society of Anesthesiologists (ASA) score, tumour side, tumour size, tumour location (upper, middle, or lower pole), tumour type (exophytic, mesophytic, or endophytic), operating room time, estimated blood loss, warm ischaemic time, length of hospital stay, histology, and margin distance. Haemoglobin levels were checked preoperatively, on postoperative day 1, and upon discharge. The difference between preoperative and 3-month postoperative serum creatinine was used to assess renal functional outcome.

The tumour was classified as exophytic if more than 50% of it was external to the line of the renal capsule, and mesophytic if 50% or more of the tumour was deep to the line of the renal capsule. Endophytic tumours were completely intraparenchymal with no renal surface change.

Statistical analysis was performed with Statistical Package for the Social Sciences (Windows version 16.0; SPSS Inc, Chicago [IL], US), with significance defined as a P value of less than 0.05 with a 2-tailed *t* test and unequal distribution. Analysis was based on the intention-to-treat principle.

Laparoscopic partial nephrectomy

We generally adopted the technique described by Haber and Gill for LPN.[14] Under general anaesthesia, a 5-French open-ended ureteral catheter was inserted cystoscopically as needed for intra-operative retrograde methylene-blue injection. The patient was placed in a modified lateral position. The pneumoperitoneum was obtained by an open technique, using the 5-port transperitoneal approach. Intra-operative laparoscopic ultrasonography was used and the line of resection scored. Hilar control was obtained either by en-bloc clamping with an externally applied laparoscopic vascular Satinsky clamp or individual clamping of vessels with laparoscopic bulldog clamps. The tumour was excised with cold scissors and the resection margins were sent for frozen section. The collecting system was repaired with 2-0 Vicryl. Renorrhaphy was performed with interrupted sutures over a pre-prepared Surgicel bolster. Use of haemostatic agents was left to the surgeon's preference.

Robot-assisted laparoscopic partial nephrectomy

The techniques and trocar placement for RPN have been described in detail by various authors.[5] We

used some important variations. A 3-arm approach was used, and the da Vinci S system with TilePro technology was docked. All operative steps were performed transperitoneally and purely robotically, with no hybridisation of the technique. The patient was placed in a modified lateral position and the table flexed 20 degrees. Hilar control was obtained by laparoscopic bulldog clamps placed by the assistant. We clamped both renal vessels individually for any right renal mass. Only the renal artery was clamped for left renal mass. The use of intra-operative ultrasonography, tumour excision, tumour bed biopsies, and collecting system repair were similar to the LPN group. Surgicel bolsters and a layer of FloSeal were applied to the defect after tumour excision in all cases. Renorrhaphy was completed with two techniques. For the initial RPN experience, a traditional tied suture closure similar to the LPN technique was used. However, it was transitioned to a sliding-clip technique[15] with Weck Hem-o-lock and LapraTy in our last three patients. No early unclamping technique[16] was practised.

Results

Overall, the 10 patients treated with RPN were similar to the 10 treated with LPN in age, ASA score and radiographic tumour size (Table 1). The mean age was 63 (range, 36-78) years in the RPN group, and 56 (range, 31-79) years in the LPN group. The mean radiographic tumour size was 27 (range, 17-50) mm in the RPN group, and 28 (range 12-50) mm in the LPN

TABLE 1. Summary statistics of perioperative data of robot-assisted laparoscopic partial nephrectomy (RPN) and standard laparoscopic partial nephrectomy (LPN)

Variable*	RPN (n=10)†	LPN (n=10)†	P value
Gender (M/F)	8/2	5/5	-
Age (years)	63 (36-78)	56 (31-79)	0.313
ASA score	2.0	1.8	0.500
Radiographic tumour size (mm)	27 (17-50)	28 (12-50)	0.895
Side (R/L)	3/7	5/5	-
Location (upper/mid/lower)	3/4/3	5/5/0	-
Type (exophytic/mesophytic/endophytic)	5/5/0	6/3/1	-
Operating room time (min)	376 (179-470)	361 (197-477)	0.722
Estimated blood loss (mL)	329 (50-700)	328 (200-550)	0.994
Warm ischaemic time (min)	31 (26-36)	40 (27-50)	0.032
Length of stay (days)	7 (5-12)	14 (6-51)	0.213
Pelvicalyceal repair (yes/no)	8/2	4/6	-
Histology (malignant/benign)	9/1	8/2	-
Pathological tumour size (mm)	27 (9-35)	28 (15-35)	0.907
Margin distance (mm)	2.8 (0.3-5.0)	2.4 (0.5-5.0)	0.728
Hb level (g/L)			
Preoperative	137 (119-151)	134 (113-153)	0.676
Postoperative day 1	121 (93-136)	114 (94-137)	0.289
Discharge	121	115	0.389
Change, preop – postop day 1	-16	-20	0.446
Serum creatinine level (mmol/L)			
Preoperative	89 (43-142)	86 (57-132)	0.804
Postoperative at 3 months	99 (50-153)	93 (70-122)	0.657
Change (mmol/L), preop – postop month 3	+10	+7	0.605
Open conversion	1 (difficult tumour localisation)	2 (both due to bleeding)	-
Intra-operative transfusion (units)	0	0	-
Postoperative transfusion (units)	1	2	-
Postoperative complication	1 (perinephric haematoma)	3 (1 perinephric haematoma, 1 urine leak, 1 lymph leak)	-

* ASA denotes American Society of Anesthesiologists, and Hb haemoglobin
† Data are shown as No., mean (range), or as otherwise stated

group. In the RPN group, there were five mesophytic and five exophytic tumours, and in the LPN group, one endophytic, three mesophytic, and six exophytic tumours. In both groups, all the tumours were T1a.

Comparison of operative data for patients having RPN and LPN revealed no significant differences in terms of operating room time (376 vs 361 minutes; P=0.722), estimated blood loss (329 vs 328 mL; P=0.994), and length of hospital stay (7 vs 14 days; P=0.213). Notably, warm ischaemic time was significantly shorter in the RPN group (31 vs 40 minutes; P=0.032). Particular note must be made in regard to the rate of pelvicalyceal system entry (80% vs 40%) which may reflect the more complex tumour nature in the RPN group. There was no intra-operative complication or transfusion for both groups. No involved margins were encountered in the frozen sections.

The mean postoperative fall in haemoglobin was 16 g/L in the RPN group and 20 g/L in the LPN group (P=0.446). Early renal outcome was comparable as shown by the increase in serum creatinine 3 months postoperatively (10 mmol/L vs 7 mmol/L; P=0.605). Both groups shared similar baseline serum creatinine levels preoperatively (89 mmol/L vs 86 mmol/L; P=0.804).

Most of the tumours were malignant in nature. The mean margin distance was 2.8 mm for RPN and 2.4 mm for LPN (P=0.728) tumours, and respective mean tumour size was also comparable (27 mm vs 28 mm; P=0.907).

In the RPN group there was one conversion to open partial nephrectomy, due to difficult tumour localisation. There were two conversions to the open technique in the LPN group, both due to significant haemorrhage.

A perinephric haematoma occurred in one patient in the RPN group, who was transfused 1 unit of packed cell. Postoperative complications occurred in three patients undergoing LPN. There was one with a perinephric haematoma, one had a urine leak, and one a lymph leak. Two units of blood were transfused to the patient with a perinephric haematoma. The other two patients were managed conservatively and the length of hospital stay was 51 and 36 days, respectively.

TABLE 2. Previously published series of robot-assisted laparoscopic partial nephrectomy[4-12*]

Study	No. of patients	Tumour size (mm)	OR time (min)	EBL (mL)	WIT (min)	Positive margin	No. of complications
Gettman et al[4]	13	35	215	170	22	1	1
Phillips et al[5]	12	18	265	240	26	0	3
Caruso et al[6]	10	20	279	240	26	0	3
Rogers et al[7]	8 (14 tumours)	36	192	230	31	0	0
Rogers et al[8]	11	38	202	220	28	0	2
Rogers et al[9]	148	28	197	183	28	6	9
Kaul et al[10]	10	20	155	92	21	0	3
Ho et al[11]	20	30	83	189	22	0	0
Michli and Parra[12]	20	27	142	263	28	0	3

* OR time denotes operating room time, EBL estimated blood loss, and WIT warm ischaemic time

TABLE 3. Previously published comparative studies of robot-assisted laparoscopic partial nephrectomy (RPN) and standard laparoscopic partial nephrectomy (LPN)[13,17-21]

Variable*	RPN vs LPN						
	Aron et al[17]	Deane et al[13]	Wang and Bhayani[18]	Benway et al[19]	Jeong et al[20]	Kural et al[21]	Present study
Study type	Matched pair	Case series	Case series	Case series	Case series	Case series	Case series
No.	12 vs 12	10 vs 11	40 vs 62	129 vs 118	31 vs 26	11 vs 20	10 vs 10
Tumour size (mm)	24 vs 29	31 vs 23	25 vs 24	29 vs 26	34 vs 24	31 vs 32	27 vs 28
OR time (min)	242 vs 256	229 vs 290	140 vs 156†	189 vs 174	170 vs 139	185 vs 226	376 vs 361
EBL (mL)	329 vs 300	115 vs 198	136 vs 173	155 vs 196†	198 vs 208	286 vs 388	329 vs 328
WIT (min)	23 vs 22	32 vs 35	19 vs 25†	20 vs 28†	21 vs 17	27 vs 36†	31 vs 40†
LOS (days)	4.7 vs 4.4	2.0 vs 3.1†	2.5 vs 2.9†	2.4 vs 2.7†	5.2 vs 5.3	NA‡	7 vs 14

* OR time denotes operating room time, EBL estimated blood loss, WIT warm ischaemic time, and LOS length of stay
† Significant results
‡ NA denotes not available

Discussion

Laparoscopic partial nephrectomy is an advanced procedure requiring rapid excision and complex suturing under time constraints posed by hilar clamping. The da Vinci system appears to have dramatically reduced the learning curve for complex laparoscopic procedures, by providing the advantages of a three-dimensional operative view and wristed robotic instrumentation.

Early studies with RPN since 2004 reported operating room times and warm ischaemic times ranging from 83 to 279 minutes, and 21 to 31 minutes, respectively (Table 2[4-12]). Intermediate-term oncological outcomes were promising as reflected by acceptable positive margin rates and no evidence of recurrence.

Although the feasibility of RPN was confirmed, no clear advantage over LPN has been apparent. To our knowledge, seven comparative studies were published including our series (Table 3[13,17-21]). The first study comparing RPN to LPN was published by Aron et al[17] from the Cleveland Clinic in 2007. They demonstrated no differences between the two procedures in terms of operating room time, estimated blood loss, warm ischaemic time or length of hospital stay. The study by Deane et al[13] also showed no significant differences between the procedures except that on average RPN patients enjoyed a shorter length of hospital stay (by 1 day). Larger series, entailing both single-surgeon and multi-institutional operations, were published recently by Wang and Bhayani[18] and Benway et al[19] from the Washington University School of Medicine. In contrast to previous studies, they showed a significant reduction in operating time, intra-operative blood loss, warm ischaemic time, and shorter lengths of hospital stay for RPN than LPN patients. Experience from Korea and Turkey were also released by Jeong et al[20] and Kural et al[21] in 2009, respectively. Both series demonstrated similar perioperative outcomes associated with RPN and LPN.

Our study represents the first RPN series and comparative study of RPN and LPN in Hong Kong. In this retrospective series, RPN appeared to confer significant benefit compared to LPN in terms of shorter warm ischaemic times. We attribute this to the ease of the dissection and reconstruction using the robotic interface, though the actual benefit of the shorter warm ischaemic times remains speculative. Evaluation of the impact of reduced warm ischaemic time on long-term renal functional outcome necessitates collection of long-term creatinine clearance data.

Notably, we were comparing the first cohort of RPN patients to the latest cohort of those having LPN; 17 LPNs has been performed in our unit since February 2003. And yet, reduced warm ischaemic time and comparable results for other perioperative parameters were achieved in the RPN group. In addition, the RPN-managed tumours were possibly more complex than those in our LPN group. This was reflected by the higher rate of pelvicalyceal repair in the RPN group. While many factors contribute to tumour complexity, the use of pelvicalyceal repair alone as the measure of tumour complexity has been supported by previous work revealing the association of collecting system repair with longer warm ischaemic time for LPN.[22,23] This implies that the actual benefit of RPN over LPN may be more substantial.

In contrast, the refinement in reconstructive techniques by using sliding-clip renorrhaphy in RPN patients poses questions about the results of our study. Indeed the technique is associated with shorter warm ischaemic time.[24] The warm ischaemic time was 32 minutes for RPN group if the results of the three patients utilising the sliding-clip technique were excluded. When this was compared to warm ischaemic time of 40 minutes for the LPN group, the P value was 0.053 (a near-significant difference).

There were fewer open conversions (1 vs 2) and postoperative complications (1 vs 3) in the RPN group as opposed to the LPN group. The enhanced articulation offered by robotics may allow rapid control over intra-operative bleeding. This may explain the absence of conversion due to haemorrhage in the RPN group, while two patients required open conversion in the LPN group. However, a haemostatic agent was used for all the patients in the RPN group while its use was left to the surgeon's discretion in the LPN group. Better visualisation and more precise repair of calyceal defects with robotics may be the reason of less postoperative urine and lymph leakage in the RPN group.

The retrospective design and our small samples, however, introduced a potential selection bias into our study. The short follow-up, especially for the RPN patients, rendered any comment on long-term oncological and renal functional outcomes invalid. With the ever-changing techniques, direct comparison of RPN and LPN is deemed difficult. One example is the description of the early unclamping technique that reduced warm ischaemic time by 50%.[16] While the use of a robotic interface reduced warm ischaemic time by 22% in our study, evolution in operative technique may have had a more significant impact on perioperative outcomes.

Robot-assisted laparoscopic partial nephrectomy is an advanced robotic procedure. The surgeon must be familiar with troubleshooting in the course of robotic surgery before embarking on RPN. It takes time for the entire operating team to gain experience with RPN. The loss of surgical control over the hilum was another caveat relevant to the procedure.

Further concerns about RPN include the cost-effectiveness of the procedure in terms of machine maintenance and disposable instruments. No cost analysis study has been reported to date.

The potential advantage of RPN in the treatment of complex endophytic and hilar renal masses had been recently investigated. With a mean tumour size of 38 mm, the perioperative outcomes of RPN and LPN were comparable.[25] Extrapolation of RPN to the treatment of T1b tumours awaits further research.

Early studies have shown promising results from robot-assisted single-port partial nephrectomy and transvaginal renal surgeries.[26,27] Comparison of different approaches to partial nephrectomy warrants further study.

Conclusions

Robot-assisted laparoscopic partial nephrectomy is emerging as an alternative to standard LPN, and provides comparable perioperative outcomes. Potentially, RPN could allow wider dissemination of minimally invasive nephron-sparing surgery. Moreover, in our series it appears to offer the advantage of decreased warm ischaemic time. As this study was limited by its small size and retrospective nature, a randomised prospective study may be appropriate to compare robot-assisted and standard LPN. Longer follow-up is essential, before we can comment on long-term oncological and renal functional outcomes.

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