SCIENTIFIC PAPER

A Comparison of Surgical and Functional Outcomes of Robot-Assisted Versus Pure Laparoscopic Partial Nephrectomy

Jae Duck Choi, MD, Jong Wook Park, MD, Hye Won Lee, MD, Dong-Gi Lee, MD, Byong Chang Jeong, MD, Seong Soo Jeon, MD, Hyun Moo Lee, MD, Han Yong Choi, MD, Seong Il Seo, PhD

ABSTRACT

Background and Objectives: Robot-assisted partial nephrectomy (RAPN) is emerging as an alternative to laparoscopic partial nephrectomy (LPN) for the treatment of small renal tumors. We compare the results of LPN and RAPN performed by a single surgeon.

Methods: Data from 100 consecutive patients who underwent LPN (n=52) or RAPN (n=48) performed by a single experienced laparoscopic surgeon between October 2007 and June 2010 were analyzed retrospectively. Perioperative data, including clinical, pathological, and functional outcomes, were compared between the LPN and RAPN groups.

Results: No significant differences were found between groups with regard to mean estimated blood loss, main operation time, warm ischemic time, intraoperative complications, postoperative complications, hospital stay, or percent reduction of hemoglobin. The mean duration of follow-up was 16.2 months for LPN patients versus 8.9 months for RAPN patients ($P<.001$). With respect to the clamping method, more artery-only clamping occurred during RAPN than LPN (38.5 vs 75%, respectively, $P=.001$). The mean pathological tumor volume for LPN was 4.0 cm^3 vs 8.2 cm^3 for RAPN ($P=.006$). The mean resected healthy tissue volume was 25.1 cm^3 for LPN versus 16.1 cm^3 for RAPN ($P=.044$). There were no significant differences in positive margins or changes in renal function between the 2 cohorts.

Conclusion: RAPN is a comparable and alternative option to LPN, providing equivalent oncological and functional outcomes, as well as comparable morbidity to LPN. Although RAPN could offer the advantages of saving more healthy marginal tissue, longer-term and larger studies are necessary to evaluate the functional advantages.

Key Words: Partial nephrectomy, Robotics, Laparoscopic, Renal function.

INTRODUCTION

Partial nephrectomy has equivalent long-term oncological outcomes and superior renal functional outcomes to radical nephrectomy. Furthermore, the length of the tumor-free margin has minimal clinical significance; a normal tissue margin of 1 mm might be sufficient to prevent local recurrence and disease progression of renal cell carcinoma.[1–3] Minimally invasive nephron-sparing surgery techniques are evolving continuously, and recent comparative studies have demonstrated favorable-to-equivalent outcomes for robot-assisted partial nephrectomy (RAPN) compared with laparoscopic partial nephrectomy (LPN), particularly with respect to warm ischemia time.[4,5] These advantages of RAPN are likely a result of the demonstrated advantages offered by the da Vinci robotic platform (Intuitive Surgical, Sunnyvale, CA), such as 3-D vision and 7 degrees of freedom of the surgical instruments, which can overcome the technical limitations of LPN.[6–8] However, it is still unclear whether RAPN has clinical advantages compared with LPN when performed by an experienced laparoscopic surgeon. To address this question, we analyzed outcomes after LPN and RAPN by a single experienced laparoscopic surgeon.

MATERIALS AND METHODS

Data for 100 consecutive patients who underwent transperitoneal RAPN (n=48) or LPN (n=52) in a university-

Department of Urology, KEPCO Medical Center, Seoul, Republic of Korea (Dr. Choi).

Department of Urology, Korea Cancer Centre Hospital, Seoul, Republic of Korea (Dr. Park).

Department of Urology, Samsung Medical Centre, Sungkyunkwan University School of Medicine, Seoul, Republic of Korea (Drs. Lee HW, Jeong, Jeon, Lee HM, Choi, Seo).

Department of Urology, Kyung Hee University School of Medicine, Seoul, Republic of Korea (Dr. Lee D-G).

Address correspondence to: Seong Il Seo, MD, PhD, Department of Urology, Samsung Medical Centre, Sungkyunkwan University School of Medicine, 50 Ilwon-dong, Kangnam-gu, Seoul, 135-710, Republic of Korea. Telephone: +82 2 3410 3556, Fax: +82 2 3410 6981. E-mail: siseo@skku.edu

DOI:10.4293/108680813X13693422521359

based tertiary referral center between October 2007 and June 2009 by a single laparoscopic surgeon were analyzed retrospectively. Inclusion criteria for LPN were a single organ-confined mass of ≤7 cm. All patients had a normal contralateral kidney. Patients younger than 18 years and those with preoperative renal dysfunction (defined as serum creatinine >1.4 mg/dL), tumor >7 cm, or preoperative radiographic evidence suspicious for lymph node or distant metastases were excluded from study. For each patient, the choice of operative methods between the 2 minimally invasive approaches was based on a joint decision by the surgeon and patient, who was appropriately informed about the surgical procedures and complications. The preoperative workup included routine laboratory tests and radiological evaluation with contrast-enhanced computed tomography or magnetic resonance imaging to delineate parameters of the renal lesion, including tumor location, size, and extent of protuberance. One radiologist reviewed the imaging studies to categorize the renal mass as exophytic, endophytic, or mesophytic, as previously defined by Finley et al.[9] In addition, tumors were classified according to the preoperative aspects and dimensions used for an anatomical classification of renal tumors (PADUA).[10] The operation time was defined as the time from when the skin incision was made until the time when the wound was closed. Pathology assessment included histological analysis of the lesion and calculation of the volume of marginal healthy renal tissue. We evaluated the excised volume of the marginal healthy tissue by subtracting the tumor volume from the total volume of the resected specimen calculated using the ellipsoid formula: width × height × length × $\pi/6$.

To evaluate functional outcomes, serum creatinine levels were measured at 1, 3, 6, and 12 months after surgery, and estimated glomerular filtration rate (eGFR) was estimated using the abbreviated Modification of Diet in Renal Disease study equation.[11] Surgical complications were classified according to the Clavien classification system updated in 2004.[12]

Patient demographics and perioperative parameters were compared between groups using the Mann-Whitney U test, Student t test, χ^2 test, analysis of variance, or Fisher exact test as appropriate. SPSS version 18.0 for Windows (IBM, Armonk, NY) was used for statistical analyses, and $P<.05$ was considered statistically significant. We described our techniques and trocar arrangement for RAPN and LPN in detail in a previous publication.[13] Next we highlight some important variations in the techniques we used in the current study.

RAPN Technique

A 4-arm technique was used in all cases. Specifically, the camera port was placed approximately 6 cm above the umbilicus to midline (renal hilar level). The 12-mm assistant port was placed just above the umbilicus to the midline. The first 8-mm working port was placed at the junction of the costal margin and the lateral edge plane of the rectus muscle. The second 8-mm working port was placed in the 2-finger medial point of the anterior superior iliac spine at an approximately 120° angle toward the patient leg from the lateral edge of the rectus muscle of the camera port level. The third 8-mm port was placed 5 cm below the umbilicus in the midline. Another 5-mm port was placed for liver retraction on the right side. A laparoscopic ultrasound probe was used to plan the resection margin. The renal hilum was accurately isolated, and then either the artery only or the entire hilum was clamped without cooling in all cases. To reduce the likelihood of ischemic damage, all patients received proper hydration and mannitol infusion (0.25 g/kg) 10 minutes before clamping.

LPN Technique

Techniques and trocar arrangement for LPN have been previously described in the literature.[14] Three ports (2×12 mm, 1×5 mm) were placed in a triangular shape. Another 10-mm port was placed on the posterior axillary line for assistance, and, if necessary, an additional 5-mm port was used for liver retraction on the right side. The operative technique was similar to that described for RAPN.

RESULTS

Patient demographic data are provided in **Table 1**. There were 33 male and 19 female patients with a mean age of 51.1 (range: 21–72) years in the LPN group, and 34 male and 14 female patients with a mean age of 50.9 (range: 24–75) years in the RAPN group. The median follow-up duration was 16.2 (range: 2–29) months for both groups. There were no significant differences in body mass index; American Society of Anesthesiologists score; tumor laterality, size, or location protuberance; comorbidity including diabetes, hypertension, and others; clinical stage; or peritoneal operation history between the 2 groups.

Table 1.
Demographic Characteristics

Characteristics	LPN (n=52)	RAPN (n=48)	*P* Value
Gender (male/female)	33/19	34/14	.662
Mean age (y) (range)	51.1 (21–72)	50.9 (24–75)	.992
Median follow-up duration (mo) (range)	16.2 (2–29)	8.9 (2–29)	<.001
Mean BMI (kg/m^2) (range)	25.2 (18.0–31.5)	24.4 (16.7–31.8)	.255
Mean ASA score (range)	1.5 (1–3)	1.5 (1–2)	.668
Laterality (left/right)	26/26	23/25	.838
Tumor size (cm) (range)	2.23 (0.8–5.7)	2.47 (0.7–5.1)	.102
Tumor location			.781
Upper	15 (28.8)	13 (27.1)	
Mid	24 (46.2)	21 (43.8)	
Lower	13 (25.0)	14 (29.1)	
Tumor depth			.864
Exophytic	16 (30.8)	16 (33.3)	
Endophytic	16 (30.8)	13 (27.1)	
Mesophytic	20 (38.4)	19 (39.6)	
PADUA score	7.8 (6–10)	8 (6–10)	.095
Clinical stage			.700
T1a	49	44	
T1b	3	4	
No. of comorbidities			.218
0	22 (42.3)	30 (62.5)	
1	27 (51.9)	16 (33.3)	
>1	3 (5.8)	2 (4.2)	
Previous operation history	16 (30.8)	9 (18.8)	.254

BMI = body mass index; ASA = American Society of Anesthesiologists.

In terms of subset analysis based on PADUA score, there was no significant difference between the 2 groups (7.8 vs 8.0, *P*=.095)

The perioperative outcomes are shown in **Table 2**. Mean operative time, estimated blood loss (EBL), and warm ischemic time (WIT) were similar between the groups (*P*>.05). With respect to the type of vascular clamping (artery only, total occlusion), more artery-only clamping was performed in the RAPN group than in the LPN group (75 vs 38.5%, respectively, *P*=.001). LPN and RAPN were completed successfully in all patients, and conversion to open surgery was not needed in any case. Intraoperative adverse events occurred in 4 LPN patients (7.7%) (2 transfusions because of bleeding, 1 polar artery ligation, 1 ureter injury requiring primary repair) and in 2 RAPN patients (4.2%) (1 transfusion, 1 spleen minor injury) (*P*=.679). Postoperative complications in the LPN group included 5 Clavien grade I complications (2 cases of pulmonary edema requiring diuretics, one case of hepatotoxicity defined as an elevation in serum aspartate aminotransferase or alanine aminotransferase level from the normal range after surgery, 2 cases of electrolyte unbalance), 1 Clavien grade II complication (seizure requiring medical treatment), and 1 Clavien grade III complication (urine leak requiring insertion of a double-pigtail stent). Adverse events in the RAPN group included 4 Clavien grade I complications (2 cases of hepatotoxicity, 2 cases of electrolyte unbalance), and 1 Clavien grade II complication (postoperative transfusion required because of gross hematuria for intrarenal hematoma rather than an arteriovenous fistula or a pseudoaneurysm). There were no differences in

Table 2.
Perioperative Outcomes

Characteristics	LPN (n=52)	RAPN (n=48)	*P* Value
Mean operative time (min) (range)	263.8 (123–454)	258.6 (119–469)	.871
Mean EBL (mL) (range)	207.6 (20–600)	217.4 (50–700)	.362
Mean WIT (min) (range)	33.4 (19–74)	32.1 (19–58)	.855
Clamping method			.001
Artery-only	20 (38.5)	36 (75)	
Total occlusion	32 (61.5)	12 (25)	
Intraoperative complication	4 (7.7)	2 (4.2)	.679
Transfusion	2	1	
Open conversion	0	0	
Other complication	Polar artery ligation = 1	Spleen minor	
	Ureter injury = 1	tearing = 1	
Postoperative complication*	7 (13.5)	5 (10.4)	.761
Grade I	5	4	
Grade II	1	1	
Grade ≥III	1	0	
Hospital stay (days) (range)	8.2 (5–13)	7.8 (6–9)	.177
Mean preoperative Hb (g/dL) (range)	14.1 (10.5–16.8)	14.2 (9.3–17.1)	.829
Mean postoperative Hb at discharge (g/dL) (range)	13.6 (8.9–16.4)	13.5 (9.0–16.5)	.783
% decrease of Hb	–3.9	–5.0	.321
No recurrence (n)	52 (100)	48 (100)	NS

Hb = hemoglobin.
*Clavien classification.

perioperative changes in hemoglobin levels or length of hospital stay between the 2 groups. No recurrences were observed in either the RAPN or LPN group until the final follow-up period.

The pathological results are presented in **Table 3**. The final pathology revealed renal cell carcinoma in 86.5% (45/52) of LPN patients and 85.4% (41/48) of RAPN patients. Fuhrmann grade was not significantly different between the 2 groups. In the LPN group, there were 98% (44/45) pT1a and 2% (1/45) pT1b tumors, whereas in the RAPN group, there were 93% (38/41) pT1a, 5% (2/41) pT1b, and 2% (1/41) pT3a tumors. Although two patients in the LPN group had focal positive surgical margins (PSMs), no patients in the RAPN group had PSMs (*P*=.581). One of 2 patients with PSMs underwent radical nephrectomy immediately, and there was no pathological evidence of remnant tumor in the nephrectomy specimen. The other is free of recurrence 29 months after surgery with surveillance. The mean final tumor volume was significantly different between the 2 groups (4.0 cm^3 in the LPN group vs 8.2 [range: 1.6–33] cm^3 in the RAPN group, *P*=.006). In contrast, the mean resected healthy tissue volume was greater in the LPN group than in the RAPN group (25.1 vs 16.1 cm^3, respectively, *P*=.044). The mean greatest safety margin was significantly different between the groups (5.3 mm for the LPN group vs 2.2 mm for the RAPN group, *P*=.009). Both mean preoperative serum creatinine (mg/dL) and eGFR (mL/min) were similar between the groups (0.90 vs 0.87 mg/dL and 90.1 vs 94.0 mL/min/1.73 m^2, *P*=357 and *P*=.241, respectively). There were also no significant differences in serum creatinine levels or eGFR at 1, 6, and 12 months after surgery between the LPN and RAPN groups (*P*>.05).

DISCUSSION

Although nephron-sparing surgery is not the standard treatment option for small renal tumors from an oncological perspective, it seems to preserve renal function,

Table 3.
Pathological Outcomes

Characteristics	LPN (n=52)	RAPN (n=48)	*P* Value
Malignant (RCC)			—
Clear cell	39 (86.7)	35 (85.4)	
Papillary	2 (4.4)	3 (7.3)	
Chromophobe	3 (6.7)	3 (7.3)	
Unclassified	1 (2.2)	0	
Other malignancy	Ewing's sarcoma = 1		—
Benign			—
Oncocytoma		3	
Angiomyolipoma	4	4	
	Urinoma = 1		
	Inflammatory		
	myofibroblastic tumor = 1		
Fuhrmann grade			.171
I	1 (2.2)	0	
II	22 (48.9)	16 (39.0)	
III	22 (48.9)	25 (61.0)	
IV	0	0	
Positive surgical margin	2	0	.581
Stage (pT)			.581
pT1a	44	38	
pT1b	1	2	
pT3a	0	1	
Mean greatest safety margin (mm)	5.3	2.2	.009
Mean resected healthy tissue volume (cm^3) (range)	25.1 (1.9–92.1)	16.1 (0.6–71.2)	.044
Mean tumor volume (cm^3) (range)	4.0 (0.3–25.6)	8.2 (1.6–33)	.006

RCC = renal cell carcinoma.

thereby improving the long-term overall health outcomes of patients.[2,15,16] LPN has recently emerged as a viable alternative for the surgical management of small renal masses, with oncological and functional outcomes similar to open partial nephrectomy.[17,18] However, LPN is technically challenging; advanced laparoscopic skills are required to perform intracorporeal laparoscopic suturing at often difficult angles and repair the defect under the time constraints of warm ischemia.[19] Recently, RAPN has begun to emerge as a paradigm in renal oncological surgery. The development of the da Vinci surgical system (Intuitive Surgical) has enabled more urologists to overcome the challenges associated with complex laparoscopic reconstructive procedures.[5,20] Recent studies demonstrated that the early outcomes of RAPN are at least comparable with those achieved using the traditional laparoscopic approach, whereas other studies have reported that RAPN is superior to the traditional laparoscopic approach.[5,20,21] We conducted the present study to compare a single surgeon's experience of conventional LPN with his experience of RAPN. In a previous report, RAPN had significant advantages compared with LPN, including shorter ischemic times and a shorter hospital stay, based on analysis of the LPN results obtained by a surgeon with intensive laparoscopic training and RAPN results for initial robotic cases.[5] In another multi-institutional retrospective review of these 2 approaches (118 LPN cases, 129 RAPN cases) based on procedures performed by 3 experienced mini-

mally invasive surgeons, RAPN was shown to be a safe and viable alternative to LPN, providing the advantages of decreased hospital stay as well as significantly less EBL and shorter WIT.[4] However, Jeong et al[22] reported a shorter operative time for LPN than for RAPN (139 vs 169 minutes, respectively, P=.034), whereas tumor size, EBL, WIT, hospital stay, and associated morbidity were not significantly different between the 2 groups. In our study, no significant difference was found between the 2 groups with regard to age, body mass index, comorbidity, radiological tumor size, location, extent of protuberance, or even PADUA score. Although the perioperative surgical complications measured in this study fail to support a significant advantage of RAPN over LPN, there is a trend toward fewer complications using the robotic approach. Although the pathological tumor volume was larger in RAPN cases than in LPN cases, the resected healthy tissue volume was smaller in the RAPN group (Table 3). The reason for this result is not entirely clear. In our opinion, this may be due to more comfortable instrumentation and better visualization during RAPN compared with LPN, such as 3-D stereoscopic vision with easier angles and multijointed wrested instruments.[7,8,21] Therefore, RAPN may enable the surgeon to excise closer to the tumor and thus preserve more healthy renal tissue. Moreover, it is possible that the poor ergonomics and technical limitations of LPN increased the surgeon's anxiety about positive surgical margins, resulting in a larger margin of normal tissue surrounding the tumor. In a previous multi-institutional study comparing 118 LPN and 129 RAPN cases, although there was a 4-fold increase in the incidence of positive margins in the RAPN group compared with the LPN group, this result was not statistically significant (3.9% vs 0.8%, respectively, P=.11).[4] The authors of this multi-institutional study suggested that this could have been a result of the learning curve for RAPN not having been surpassed. No positive margin case for our RAPN series may be attributed to the previously cumulative experiences of LPN cases and the robotic technical advantages.

Furthermore, our data clearly indicate that regardless of tumor characteristics, RAPN sacrifices less healthy tissue volume than LPN. Therefore, if we can save more renal parenchymal tissue with RAPN, parenchymal suturing at the hilar area can be done more easily because there are sufficient tissues for renorrhaphy. We believe this is one of the technical advantages of RAPN. We found a similar mean WIT between the LPN and RAPN groups. This result may have been contributed by an immature renal hilar control of laparoscopy-naïve assistants during RAPN. The assistants involved in the RAPN procedure are crucial to the success and outcome of surgery. During LPN, the surgeon has to control the renal pedicle by him- or herself, whereas in RAPN, the bedside surgeon places the bulldog clamps on the renal pedicle and creates countertension during tumor excision. Therefore, the bedside surgeon during RAPN should be well experienced in standard laparoscopy and be trained in the use of laparoscopic instruments. We believe that our slightly prolonged WIT of 32 minutes during RAPN compared with that reported by published RLPN series (mean WIT of 19–28 minutes) will decrease as the experience of the operator and assistant increases.[4,19] More artery-alone clamping methods were used during RAPN than during LPN in our study. Recent studies have suggested that artery-only occlusion during LPN may provide superior renal preservation, and we have therefore shifted our focus to artery-only occlusion when performing surgery.[22] In the present study, focal microscopic positive margins on permanent section were encountered in 2 of 52 (4%) LPN patients but in no RAPN patients. These findings are consistent with previous reports (positive margin rate 1.3% to 6.3% for LPN, 0% for RAPN).[4,5,24,25] Partial nephrectomy may still result in some decrease in overall renal function. We found that the extent of postoperative decrease in renal function was similar between the 2 groups in terms of both serum creatinine levels and eGFR (Table 4). However, our renal functional results may potentially have been masked by the compensatory role of the normal contralateral kidney. In addition, renal volume reduction was a significant prognostic factor for functional reduction in previous reports.[12,26] We believe that the substantial reduction in healthy tissue volume—from 25.1 cm^3 overall in the LPN group to 16.1 cm^3 overall in the RAPN group—represents perhaps the most important parameter that differed between the groups. However, the actual clinical benefit of this reduction in healthy tissue volume remains speculative because long-term functional data are needed to evaluate the actual impact of reduced healthy tissue volume on long-term functional outcomes. Our study had several limitations. It was a retrospective nonrandomized study, which can introduce a number of unknown biases; although there was no difference in tumor size as a single measurement, there was a significant difference in tumor volume, which is a more accurate reflection of tumor size than single greatest dimension. Second, there is the bias of sequential series. Because most of the robotic cases were done after the surgeon was more experienced in pure laparoscopic surgery, the more

recent robotic cases should be expected to be faster with fewer complications. Third, our results are based on a single surgeon's experiences. Ultimately, a randomized, controlled, multicenter trial is needed to confirm our results. Additional long-term comparative studies to assess cancer control and long-term renal function outcomes are also needed. Finally, our sample size may not have been powered well enough to demonstrate differences in complications, and most of the tumors treated in this study were clinical T1a lesions. Therefore, future studies should explore whether the advantages we noted for these smaller lesions would also apply to larger and more complex lesions.

CONCLUSION

Our results demonstrate that RAPN is a safe and viable alternative to LPN for small renal tumors, with comparable surgical and functional outcomes. In particular, the resected healthy tissue volume was smaller in the RAPN group than in the LPN group. Although this appears advantageous, there is still no significant difference with respect to serum creatinine/eGFR between the groups, and further follow-up is necessary.

References:

1. Fergany AF, Hafez KS, Novick AC. Long-term results of nephron sparing surgery for localized renal cell carcinoma: 10-year followup. *J Urol.* 2000;163:442–445.

2. Huang WC, Elkin EB, Levey AS, Jang TL, Russo P. Partial nephrectomy versus radical nephrectomy in patients with small renal tumors—is there a difference in mortality and cardiovascular outcomes? *J Urol.* 2009;181:55–61; discussion 61–52.

3. Mabjeesh NJ, Avidor Y, Matzkin H. Emerging nephron sparing treatments for kidney tumors: a continuum of modalities from energy ablation to laparoscopic partial nephrectomy. *J Urol.* 2004;171:553–560.

4. Benway BM, Bhayani SB, Rogers CG, et al. Robot assisted partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: a multi-institutional analysis of perioperative outcomes. *J Urol.* 2009;182:866–872.

5. Wang AJ, Bhayani SB. Robotic partial nephrectomy versus laparoscopic partial nephrectomy for renal cell carcinoma: single-surgeon analysis of >100 consecutive procedures. *Urology.* 2009;73:306–310.

6. Gettman MT, Blute ML, Chow GK, Neururer R, Bartsch G, Peschel R. Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with DaVinci robotic system. *Urology.* 2004;64:914–918.

7. Kaul S, Laungani R, Sarle R, et al. da Vinci-assisted robotic partial nephrectomy: technique and results at a mean of 15 months of follow-up. *Eur Urol.* 2007;51:186–191; discussion 191–182.

8. Michli EE, Parra RO. Robotic-assisted laparoscopic partial nephrectomy: initial clinical experience. *Urology.* 2009;73:302–305.

9. Finley DS, Lee DI, Eichel L, Uribe CA, McDougall EM, Clayman RV. Fibrin glue-oxidized cellulose sandwich for laparoscopic wedge resection of small renal lesions. *J Urol.* 2005;173:1477–1481.

10. Ficarra V, Novara G, Secco S, et al. Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. *Eur Urol.* 2009;56:786.

11. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med.* 1999;130:461–470.

12. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg.* 2004;240:205–213.

13. Choi JD, Park JW, Choi JY, et al. Renal damage caused by warm ischaemia during laparoscopic and robot-assisted partial nephrectomy: an assessment using Tc 99m-DTPA glomerular filtration rate. *Eur Urol.* 2010;58:900–905.

14. Haber GP, Gill IS. Laparoscopic partial nephrectomy. Contemporary technique and outcomes. *Eur Urol.* 2006;49:660–665.

15. Van Poppel H, Da Pozzo L, Albrecht W, et al. A prospective, randomized EORTC intergroup phase 3 study comparing the oncologic outcome of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. *Eur Urol.* 2011;59:543–552.

16. Chow WH, Devesa SS, Warren JL, Fraumeni JF Jr. Rising incidence of renal cell cancer in the United States. *JAMA.* 1999;281:1628–1631.

17. Lane BR, Gill IS. 5-year outcomes of laparoscopic partial nephrectomy. *J Urol.* 2007;177:70–74; discussion 74.

18. Marszalek M, Meixl H, Polajnar M, Rauchenwald M, Jeschke K, Madersbacher S. Laparoscopic and open partial nephrectomy: a matched-pair comparison of 200 patients. *Eur Urol.* 2009;55:1171–1178.

19. Gautam G, Benway BM, Bhayani SB, Zorn KC. Robot-assisted partial nephrectomy: current perspectives and future prospects. *Urology.* 2009;74:735–740.

20. Ahlering TE, Skarecky D, Lee D, Clayman RV. Successful transfer of open surgical skills to a laparoscopic environment

using a robotic interface: initial experience with laparoscopic radical prostatectomy. *J Urol.* 2003;170:1738–1741.

21. Patel HR, Linares A, Joseph JV. Robotic and laparoscopic surgery: cost and training. *Surg Oncol.* 2009;18:242–246.

22. Jeong W, Park SY, Lorenzo EI, OH CK, Han WK, Rha KH. Laparoscopic partial nephrectomy versus robot-assisted laparoscopic partial nephrectomy. *J Endourol.* 2009;23:1457–1460.

23. Gong EM, Zorn KC, Orvieto MA, Lucioni A, Msezane LP, Shalhav AL. Artery-only occlusion may provide superior renal preservation during laparoscopic partial nephrectomy. *Urology.* 2008;72:843–846.

24. Breda A, Stepanian SV, Liao J, et al. Positive margins in laparoscopic partial nephrectomy in 855 cases: a multi-institutional survey from the United States and Europe. *J Urol.* 2007; 178:47–50; discussion 50.

25. Desai PJ, Andrews PE, Ferrigni RG, Castle EP. Laparoscopic partial nephrectomy at the Mayo Clinic Arizona: follow-up surveillance of positive margin disease. *Urology.* 2008;71:283–286.

26. Porpiglia F, Renard J, Billia M, et al. Is renal warm ischemia over 30 minutes during laparoscopic partial nephrectomy possible? One-year results of a prospective study. *Eur Urol.* 2007; 52:1170–1178.