

LAPAROSCOPIC PARTIAL NEPHRECTOMY FOR RENAL MASSES: EFFECT OF TUMOR LOCATION

RAMAKRISHNA VENKATESH, KYLE WELD, CAROLINE D. AMES, SHERBOURNE R. FIGENSHAU, CHANDRU P. SUNDARAM, GERALD L. ANDRIOLE, RALPH V. CLAYMAN, AND JAIME LANDMAN

ABSTRACT

Objectives. To report our single institutional experience of laparoscopic partial nephrectomy (LPN) for enhancing renal masses and evaluate outcomes and histopathologic findings with respect to the location of the renal mass.

Methods. A retrospective review of LPN for 123 renal masses completed by 7 urologists was performed. Of these lesions, 49 (40%) were exophytic, 19 (15.5%) endophytic, 47 (38%) mesophytic, and 8 (6.5%) were hilar. We defined exophytic as more than 60%, mesophytic as 40% to 60%, and endophytic as less than 40% of the renal mass protruding off the surface of the kidney on radiologic imaging studies. Hilar lesions were those located within 5 mm of the renal hilar structures, regardless of the surface characteristics.

Results. The mean tumor size was 2.6 cm (range 1 to 9). Hilar vessel clamping was performed during 55 procedures (44.7%); the mean warm ischemia time was 27 minutes (range 12 to 52). On final histopathologic examination, 3 patients (2.5%) had positive tumor resection margins. Overall, 26 (20.6%) complications occurred. The complication rate was significantly less for patients who underwent LPN for an exophytic (10%) or a mesophytic (12.8%) mass than for those with an endophytic (47%) or a hilar (50%) mass. Histopathologic examination of the renal masses revealed malignant pathologic features in 86 (69%) and benign findings in 37 (31%). In our series, only 55% of exophytic tumors were malignant and, if malignant, were invariably low grade (96%).

Conclusions. The complications of LPN and the malignancy rate of the renal lesions were related to the tumor location within the kidney. UROLOGY 67: 1169–1174, 2006. © 2006 Elsevier Inc.

A combination of the established long-term efficacy of open partial nephrectomy for small renal tumor and the obvious patient benefits of decreased morbidity and expedited convalescence from renal laparoscopy have stimulated interest in laparoscopic partial nephrectomy (LPN) for renal masses.^{1–5} Increased laparoscopic surgical experience, improvement in operative techniques, the development of novel laparoscopic technologies, and advances in preoperative and intraoperative imaging have also fueled interest in LPN. Furthermore, interest has been growing in nephron-spar-

ing surgery because of the increased number of smaller and incidentally noted renal masses combined with the realization that the excised tumor-free margin need only be 1, rather than 10, mm.

We report our single institutional experience and our evolving technique for performing LPN. Furthermore, we examined the effect of tumor location on the surgical and histopathologic outcomes. Specifically, all lesions were divided into exophytic, endophytic, mesophytic, and hilar lesions.

MATERIAL AND METHODS

With the approval of the institutional review board, we performed a review of patients who underwent LPN for an enhancing renal mass from February 2000 to September 2004. LPN was attempted in 126 patients. It was successfully performed for 123 renal masses in 121 patients. Seven different surgeons with varying levels of laparoscopic experience in renal surgery performed the procedures. All patients underwent a preoperative radiologic evaluation with contrast-enhanced computed tomography or magnetic resonance imaging to delineate the renal lesion's parameters, including

From the Division of Urology, Washington University School of Medicine, St. Louis, Missouri; Department of Urology, University of Indiana, Indianapolis, Indiana; and Department of Urology, University of California, Irvine, California

Reprint requests: Ramakrishna Venkatesh, M.D., Division of Urology, Department of Surgery, Washington University School of Medicine, 4960 Children's Place, Campus Box 8242, St. Louis, MO 63110. E-mail: venkateshr@wudosis.wustl.edu

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location, size, depth, and relation to hilar vessels and collecting system. These imaging studies were used to determine the surface characteristics of the renal mass. Most imaging studies (computed tomography or magnetic resonance imaging) were performed within our hospital facility according to the standard renal protocol, with 2-mm slice cuts. Nineteen studies were performed at an outside facility. As originally suggested by Finley *et al.*,⁶ we defined exophytic tumors as those in which the lesion extended more than 60% off the natural surface of the kidney, endophytic tumors were defined as less than 40% of the lesion extending off the surface of the kidney, and mesophytic were defined as those lesions extending 40% to 60% off the surface of the natural border of the kidney. Hilar lesions were defined as those located within 5 mm of the renal hilar structures, regardless of their surface characteristics. Two attending urologists reviewed the imaging studies to categorize the renal mass as exophytic, endophytic, mesophytic, or hilar. However, nine imaging studies required review by a radiologist to classify the mass as belonging to the mesophytic or endophytic group.

The rest of the other data collected included renal mass location, use of renal hilar vascular clamping, collecting system closure, estimated blood loss, tumor resection margin, complications, and tumor histopathologic findings. The nature of complications obtained from both the inpatient and outpatient medical records included intraoperative or postoperative bleeding, urine leakage, need for dialysis, deep venous thrombosis, and wound infection.

Depending on the tumor location and previous abdominal surgery, a transperitoneal or retroperitoneal approach was used with the patient in the lateral decubitus position. The hilar vessels were dissected before exposure of the renal mass, depending on the location of the mass and surgeon preference. A laparoscopic ultrasound scan was used to guide the surgeon to determine the depth of the renal transection. Laparoscopic bulldog clamps (Aesculap, B. Braun Medical, Bethlehem, Pa) were applied to the renal artery in 30 patients or the renal artery and vein en masse in 22 patients when hilar control was used. Renal hypothermia was achieved through a retrograde intrarenal cooling technique in 6 patients, as described previously.^{7,8} Renal parenchymal hemostasis was achieved with bipolar electrocautery forceps, a wet monopolar radiofrequency device (Tissue Link Floating Ball, Tissue Link Medical, Dover, NH), and/or intracorporeal sutures (2-0 Vicryl on a CT needle) over a bolster, including fibrin glue (Tisseel VH fibrin sealant, NHS, Hackensack, NJ) or FloSeal (Baxter Healthcare, Fremont, Calif) application. The hemostatic techniques applied were surgeon dependent. The collecting system closure was performed by intracorporeal suturing with 3-0 Vicryl on an RBI needle. The excised renal mass, or a cold cup biopsy of the deepest/suspicious area, was sent for frozen section analysis to examine the deep resection margin in 84 (71%) of the patients.

The Shapiro-Wilk normality test was used to evaluate the distribution of the variables. The categorical variables were compared using a chi-square test or Fisher's exact test, as appropriate. The continuous variables were compared using analysis of variance with multiple comparison adjustments (parametric or nonparametric).

RESULTS

A total of 123 renal masses were laparoscopically resected. LPN was attempted in 126 patients and successfully completed in 121 patients. Conversion to open partial nephrectomy was performed in 3 patients—in 2 because of positive tumor resection margins on frozen section analysis and in 1

TABLE 1. Complications and histopathologic features of renal masses

Complications	26 (20.6)
Intraoperative	8 (6.3)
Hemorrhage	3
Hypercarbia	1
Conversion to total nephrectomy (positive margin and bleeding)	2
Conversion to open partial nephrectomy (positive margin)	2
Postoperative	18 (14.3)
Urine leak	13
Ileus	2
Postoperative anemia requiring blood transfusion	2
Myocardial infarction and respiratory failure	1
Histopathologic features (n = 123 lesions)	
Renal cell carcinoma	86 (69)
Benign lesions	37 (31)
Angiomyolipoma	11
Oncocytoma	8
Leiomyoma	4
Hemorrhagic cyst	2
Benign cyst	11
Metanephric adenoma	1

Data presented as number, with percentages in parentheses.

because of difficulty in dissecting the renal mass, which was densely adherent to the liver. None had tumor at the final surgical resection margin. In 2 patients, laparoscopic total nephrectomy was performed because of intraoperative bleeding from the renal parenchyma at the resection site, including a positive surgical tumor margin in 1 patient. Four patients had bilateral renal masses, one of whom underwent simultaneous bilateral LPN.

Of the 121 patients, 65 (54%) were men and 56 (46%) were women; the mean age was 58.2 years (range 39 to 89). Of the 123 renal masses, 99 (80.4%) were solid and 24 were complex cystic masses on preoperative imaging. The mean tumor size on preoperative imaging was 2.6 cm (range 1 to 9). Upper pole, interpolar, and lower pole masses accounted for 32 (27%), 58 (47%), and 33 (26%), respectively. Of the 58 interpolar masses, 8 were hilar masses. The mean operative time was 3.4 hours (range 1.1 to 5.9). Overall, 26 complications (20.6%) occurred in 126 patients (Table 1). The mean estimated blood loss during each LPN was 269 mL (range 50 to 3000). Three patients had an estimated blood loss of more than 1 L; in all three, the bleeding was from the renal bed. In 2 patients, the renal hilum was clamped. One required additional parenchymal intracorporeal suturing for hemostasis, and the other required laparoscopic nephrectomy because of continued bleeding. The median hospital stay was 3 days

TABLE II. Patient characteristics, complications, and histopathologic findings by tumor surface nature

Characteristic	Exophytic	Mesophytic	Endophytic	Hilar	P Value
Patients (n)	49 (39.8)	47 (38.2)	19 (15.4)	8 (6.5)	
Average age (yr)	59.5	60.0	53.3	51.6	0.45
Average tumor diameter (cm)	2.88	2.54	2.31	2.16	0.78
Solid tumor	36 (73.5)	42 (89.4)	13 (68.4)	7 (87.5)	0.44
Transperitoneal approach	36 (73.5)	38 (80.9)	15 (78.9)	5 (62.5)	0.62
Intraop US	24 (49.0)	19 (40.4)	19 (100)	3 (37.5)	<0.001
Vessel clamp	24 (49.0)	15 (31.9)	16 (84.2)	7 (87.5)	<0.001
Average ischemia time	25.9	26.3	29.8	29.0	
Collecting system violation	9 (18.4)	10 (21.3)	13 (68.4)	6 (75.0)	<0.001
Average estimated blood loss (mL)	274	233	370	213	0.54
Average OR time (min)	184	220	234	169	0.04
Complications	5 (10.2)	6 (12.8)	9 (47.4)	4 (50.0)	<0.001
Urinary leak	3 (6.1)	1 (2.1)	5 (26.3)	4 (50.0)	<0.001
Hemorrhage	2 (4.1)	2 (4.3)	1 (5.3)	0 (0)	1.00
Positive surgical margin	0 (0)	1 (2.1)	2 (10.5)	0 (0)	
Malignant	27 (55.1)	36 (76.6)	16 (84.2)	7 (87.5)	0.03
Grade I-II/IV	26 (96.3)	31 (86.1)	12 (75.0)	6 (85.7)	0.04
Average hospital stay (days)	2.8	4.0	2.8	3.9	0.60

KEY: Intraop = intraoperative; US = ultrasonography; OR = operating room.

Data presented as number of patients, with percentages in parentheses, unless otherwise noted.

(range 1 to 36). One patient stayed in the hospital for 36 days because of respiratory failure and myocardial infarction after LPN. Overall, malignant pathologic features were found in 86 (69.9%) of the renal masses excised (Table I).

A total of 8 patients (6.6%) had positive tumor surgical margins at the first resection of the renal mass. All were during the investigators' early experience (first 50 LPNs). Three patients underwent laparoscopic resection of additional tissue to achieve a negative margin, and two underwent conversion to open partial nephrectomy to obtain a negative surgical tumor margin after frozen section analysis had shown a positive tumor surgical margin. Two patients with nonimperative indications for partial nephrectomy underwent conversion to laparoscopic total nephrectomy. One patient with a positive surgical margin who was 81 years old has been followed up with observation. Overall, 3 patients (2.5%) had a positive surgical margin on the final pathologic examination. With a mean follow-up of 16 months (range 4 to 48), no tumor recurrences have developed.

Of the 123 renal masses, 49 (39.8%) were exophytic, 47 (38.2%) were mesophytic, 19 were (15.4%) endophytic, and 8 (6.5%) were hilar (Table II). No significant difference in the estimated blood loss was found among these groups ($P = 0.54$). The overall complication rate was significantly less for patients who underwent LPN for an exophytic (10%) or a mesophytic (12.8%) mass than for those with an endophytic (47%) or a hilar (50%) mass ($P < 0.001$; Table II). No significant differences were found in the complication rates

between the exophytic and mesophytic groups ($P = 0.7$). The complication rates for the exophytic and mesophytic groups were significantly less than for the endophytic ($P < 0.05$) and hilar ($P < 0.05$) groups. No significant differences were found in the complication rates between the endophytic and hilar groups ($P = 1.0$). No difference was found in the margin-positive rates between LPN performed with and without hilar vessel control.

Upper pole tumors resulted in the greatest average blood loss and complication rate (25.8%) relative to interpolar (12%) and lower polar (18%) tumors. A transperitoneal approach was obtained during LPN for 94 renal masses (76.4%). The retroperitoneal group had a greater complication rate (34.5%) than the transperitoneal group (15%; $P < 0.05$). Collecting system closure was required in 38 patients (31%). The postoperative complication rate was significantly greater (34.2%) in the group in which collecting system closure was required compared with the group without it (13%; $P < 0.05$). Urine leaks were defined as persistent drainage of urine after 48 hours. Urinary leakage was seen in 13 patients (10.7%). The urine leak rate was greater for those with endophytic (26%) and hilar (50%) masses than for those with exophytic (6%) or mesophytic (2%) masses ($P < 0.05$). As expected, the urinary leak rate was significantly less for the exophytic and mesophytic groups than for the endophytic ($P < 0.05$) and hilar ($P < 0.05$) groups.

All seven surgeons had performed more than 50 renal laparoscopic procedures other than LPN. The total number of LPNs performed varied from 8 to

52 by the different surgeons. The overall complication rates were not significantly different, because the case selection was different among the different surgeons. The surgeons with the most experience performed the more complex LPNs and the less complex, exophytic, small-mass LPNs were performed by the surgeons with minimal LPN experience. Surgeons less experienced with intracorporeal suturing should expect longer warm ischemic times, and surgeons early in their experience with LPN should consider this.

The tumor location was noted to predict the rate of malignancy. Only 27 (55%) of the exophytic renal masses had malignant histopathologic features compared with 31 (86%), 12 (75%), and 6 (85.7%) of the mesophytic, endophytic, and hilar masses, respectively ($P < 0.05$). Additionally, the fraction of tumors having high Fuhrman nuclear grade features was only 3.7% of the exophytic compared with 13.9% of the mesophytic and 25% of the endophytic tumors ($P < 0.05$) in our series.

COMMENT

The first laparoscopic nephrectomy was performed in 1990 by Clayman *et al.*⁹ and was shortly followed by reports of LPN for benign disease and renal tumor in an adult.^{4,5} Ramani *et al.*¹⁰ reported on their complications in 200 patients who underwent LPN for suspected renal tumor. Of their 200 patients, 33% had complications: intraoperative in 5.5%, postoperative in 12%, and delayed in 15.5%. Urologic complications (hemorrhage in 9.5% and urine leak in 4.5%) were seen in 18% and nonurologic complications in 15% of their patients. More recently, Link *et al.*¹¹ reviewed their experience of 217 LPNs for enhancing renal masses and reported a postoperative complication rate of 10.6%. In their series, 66% of enhancing renal masses were malignant. Guillonneau and colleagues¹² reported their experience comparing LPN with and without clamping of the renal hilar vasculature. Of their 28 patients, 16 (57%) underwent LPN with hilar vessel clamping.¹² The mean estimated intraoperative blood loss was 708 mL and 270 mL in the non-clamped and clamped groups, respectively. We had an overall complication rate of 20.6%, and a positive margin rate of 6.6% at the initial resection. The complication rate was not increased in the mesophytic group who had no hilar vessel control (12.9%; two thirds of the patients in this group) compared with the group with hilar vessel control (11.7%, $P = 0.2$). The high positive margin rate was likely the product of the learning curves of the multiple surgeons with varied laparoscopic experience. The positive margins mainly occurred during the early portions of our experience. Currently, we perform and recommend intraoperative laparo-

scopic ultrasonography for all LPN procedures to evaluate the tumor depth and its relation to the collecting system to achieve a tumor-free surgical margin.

The overall urine leak rate in our series was 10.7%, greater than that for most open partial nephrectomy series.^{2,3} This could have partly been because of technical reasons, as many different surgeons were performing the procedures. In the current series, we had a 50% urine leak rate in patients undergoing LPN for hilar tumors and 26% for those with endophytic tumors. As such, for these tumors, we have altered our technique to include insertion of a ureteral catheter at the beginning of the LPN procedure. Saline injection through the ureteral catheter facilitates precise identification of the site of collecting system violation and confirmation of a watertight closure of the collecting system. Additionally, a double-J stent is routinely used in these patients for postoperative renal decompression.

Table III demonstrates the reported worldwide experience with LPN and compares these results with those of the present series.

A retrospective study from the Cleveland Clinic evaluated the treatment outcomes and histopathologic findings according to the tumor location in relation to the renal sinus in patients undergoing open partial nephrectomy for small (less than 4 cm) renal masses.¹³ The mass was categorized as central or peripheral. The peripheral tumor was defined as peripherally located in the kidney and enveloped by renal cortical or medullary parenchyma with no extension into the renal sinus. Central tumors extended into the renal sinus. Nephron-sparing surgery was used to treat 19 central (54%) and 67 peripheral (61%) carcinomas. No significant differences were found in the complication rates between the peripheral (12%) and central (20%) groups in this open partial nephrectomy series. The reported overall complication rate for LPN (10% to 33%) is greater than that for open partial nephrectomy (4% to 30%) in published reports.¹⁰ However, many of the complications in our series were urine leak.

The above open series has also demonstrated no significant biologic differences in terms of tumor stage or grade between centrally versus peripherally located renal cell carcinomas with the aforementioned features. Grade 1 to 2 renal cell carcinoma was present in 28 central (80%) and 85 peripheral (77%) tumors. Many of the peripheral tumors in the Cleveland series might have been considered exophytic, mesophytic or, possibly, endophytic lesions as per our categorization in the present study. This might explain the differences in the histopathologic findings between the two studies. In our series, nearly one half of the exo-

TABLE III. Reported experience of laparoscopic partial nephrectomy

Series	Patients (n)	Mean Tumor Size (cm)	Renal Tumor Clamping (%)	Hilar Vessel Clamping (%)	Collecting System Closure (%)	Mean OR Time (min)	Mean EBL (mL)	Complications (%)	Mean Hospital Stay (days)	Mean Follow-up (mo)
Ramani <i>et al.</i> , ¹⁰ 2005	200	2.9	99	99	71	199	247	33	2	12
Link <i>et al.</i> , ¹¹ 2005	217	2.6	75	75	41	186	350	10.6 (postoperatively)	3.1	12
Guillonneau <i>et al.</i> , ¹² 2003	28	2.2	57	57	39	158	490	21	4.7	7
Jeschke <i>et al.</i> , ¹⁴ 2001	51	2	0	0	0	132	282	10	5.8	34.2
Janetschek <i>et al.</i> , ¹⁵ 2000	25	1.9	0	0	0	170	287	12	5.8	22.2
Present series	126	2.6	45	45	31	204	269	20.6	3	16

Key: OR = operating room; EBL = estimated blood loss.

phytic tumors were benign and 96% of the malignant tumors were low-grade carcinomas. As such, observation with regular follow-up radiologic imaging should be considered as a management option. Our categorization of tumor location according to the surface characteristics helps to counsel patients regarding complications and preoperative planning such as the tumor approach, need for hilar vasculature control, and closure of the collecting system.

CONCLUSIONS

Intrarenal tumor location has a significant impact on the complication rate during LPN. Defining the tumor location will help provide better preoperative counseling for patients and careful planning in each case with regard to the tumor approach. The tumor location also had significant prognostic value for the determination of the malignant nature of a small exophytic renal mass. Because one half of these exophytic masses were likely to be benign and, if malignant, were invariably low grade, active observation with radiologic imaging should be an important part of the discussion with the patient regarding management options.

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EDITORIAL COMMENT

The dual imperatives of sparing renal parenchyma and achieving rapid patient convalescence have led to the development of LPN as a surgical approach for the management of renal tumors. The authors of the current series are to be commended for providing further evidence of the feasibility, safety, and efficacy of LPN.

However, it is important to highlight the current limitations of this evolving procedure to facilitate appropriate patient counseling. The various series of LPN published to date, and summarized in this report, have tended to emanate from centers of excellence. It is questionable whether the technique can be reproduced by less-experienced urologic laparoscopists.¹

Additionally, even in experienced hands and with more specific patient selection, the complication rate from LPN remains high compared with open nephron-sparing surgery.^{1,2} Particular concerns relate to the risks of urinary leakage, massive hemorrhage, positive surgical margins, and renal ischemia. The evolving nature of LPN and the associated learning curve has likely contributed to the observed morbidity and is expected to improve over time, such as has been witnessed for open nephron-sparing surgery.²

Another difference between LPN and open nephron-sparing surgery relates to the greater need for, and duration of, renal vascular clamping and the difficulty of achieving effective renal-protective parenchymal cooling. Although the precise impact of longer periods of warm ischemia in the human model on renal function remains to be better delineated, it is likely to somewhat negate the rationale behind a nephron-sparing approach.² Therefore, patients who are currently being offered LPN need to be carefully informed of the above differences between the laparoscopic and open procedures, as well as the eventual resort to a “salvage” total nephrectomy in less-experienced hands.³

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Shomik Sengupta, M.D.

Horst Zincke, M.D.

Department of Urology

Mayo Clinic

Rochester, Minnesota

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REPLY BY THE AUTHOR

We agree with the reviewers that LPN continues to evolve and requires significant technical skill. However, during the past 5 years, LPN has been increasingly performed in a routine manner, with the technique becoming increasingly standardized. Although the techniques required to perform these “advanced” procedures in 2006 have evolved from high-volume academic centers, LPN is no different from other technically advanced procedures commonly performed with skill by most urologists today, such as open radical prostatectomy and open partial nephrectomy. Early series on open partial nephrectomy reported local or renal-related complication rates of up to 37%.¹ As such, we are convinced that the urologic community will, as they have in the past, learn new skills that will have a positive impact on our patients. Initially, LPN should be performed in selected patients with a small tumor in an anatomically favorable location. Continued efforts are required to develop laparoscopic renal hypothermia techniques and to facilitate intrarenal suturing to minimize the warm ischemia time.

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Ramakrishna Venkatesh, M.D.

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