Laparoscopic Partial Nephrectomy for Centrally Located Renal Tumors

Igor Frank, Jose R. Colombo, Jr., Mauricio Rubinstein, Mihir Desai, Jihad Kaouk and Inderbir S. Gill*

From the Section of Laparoscopic and Robotic Surgery, Glickman Urological Institute, Cleveland Clinic Foundation, Cleveland, Ohio

Purpose: LPN is frequently reserved for small, peripherally located tumors. Centrally located tumors typically require complex intracorporeal suturing and reconstruction with hilar clamping, which is a laparoscopically advanced maneuver given the constraints of renal ischemia. We retrospectively compared our experience with central vs peripheral tumors treated with LPN.

Materials and Methods: Between January 2001 and March 2004, 363 patients underwent LPN for tumor. The tumor was located centrally in 154 patients and peripherally in 209. Central tumors were defined as tumors centrally extending into the kidney in direct contact with or invading into the pelvicaliceal system and/or renal sinus on preoperative 3-dimensional computerized tomography. Lesions with no contact with the pelvicaliceal system were classified as peripheral. Preoperative, intraoperative, postoperative and pathological data were compared.

Results: Central tumors were larger (median 3 vs 2.4 cm, $p < 0.001$) and had larger specimens at surgery (median 43 vs 22 gm, $p < 0.001$) than peripheral tumors. Although blood loss was similar (median 150 cc), central tumors required longer warm ischemia time (median 33.5 vs 30 minutes, $p < 0.001$), operative time (median 3.5 vs 3 hours, $p = 0.008$) and hospital stay (median 67 vs 60 hours, $p < 0.001$). A positive cancer margin occurred in 1 patient per group. Median postoperative serum creatinine was similar (1.2 vs 1.1 mg/dl). Intraoperative and late postoperative complications were comparable. However, more early postoperative complications occurred in the central group (6% vs 2%, $p = 0.05$).

Conclusions: LPN for central tumors can be performed safely by an experienced laparoscopic surgeon with perioperative outcomes comparable to those of peripheral tumors. Given the requisite laparoscopic expertise, indications for LPN should be expanded to include centrally located tumors.

Key Words: kidney, kidney neoplasms, laparoscopy, nephrectomy, outcome assessment (health care)

LPN is a complex procedure requiring advanced laparoscopic skills and it is associated with its inherent learning curve. Initially LPN was reserved for the technically easier, smaller, exophytic, peripherally located tumors. Because centrally located tumors typically require precise intracorporeal suturing and complex reconstruction, with the added time constraints imposed by renal ischemia they have laparoscopically not been approached or approached with considerable hesitation. However, with increasing laparoscopic experience and confidence indications for LPN have been carefully expanded to include more technically challenging lesions, including those that are centrally located.

Open partial nephrectomy is routinely used to treat centrally located tumors with good outcomes.[1,2] However, to our knowledge the outcomes of pure LPN for central tumors have not been specifically addressed in the literature to date. We report our experience with LPN for centrally located tumors with an emphasis on technical efficacy and perioperative outcomes. Data are compared retrospectively with LPN for peripherally located tumors.

MATERIALS AND METHODS

In the 3-year period between January 2001 and March 2004, 363 consecutive patients underwent LPN for tumor, as performed by a single staff surgeon (ISG). Data were obtained from our prospectively maintained database with Institutional Review Board approval. There were 154 patients (42%) with a central tumor and 209 (58%) with a peripheral tumor. All patients underwent preoperative 3-D CT with 3 or 5 mm cuts and video reconstruction at our institution. All CT images were specifically re-reviewed for this study to identify central and peripheral tumors. Tumors centrally extending into the kidney in direct contact with or invading into the collecting system and/or renal sinus on preoperative 3-D CT were defined as central. Tumors with no contact with the central sinus of the kidney on preoperative 3-D CT were classified as peripheral.

The preoperative characteristics assessed were patient age, sex, laterality, serum creatinine and CT findings, eg tumor location, size and proximity to the hilar structures. The intraoperative features analyzed were surgical approach (transperitoneal vs retroperitoneal), caliceal system repair, renal ischemia time, total operative time, estimated

Submitted for publication April 21, 2005.
Study received Institutional Review Board approval.
* Correspondence and requests for reprints: Section of Laparoscopic and Robotic Surgery, Glickman Urological Institute, Cleveland Clinic Foundation, 9500 Euclid Ave., A100, Cleveland, Ohio 44195 (telephone: 216-445-1530; FAX: 216-445-7031; e-mail: gilli@ccf.org).

TABLE 1. *Clinical characteristics in patients with central and peripheral tumors treated with LPN*

Feature	Central	Peripheral	p Value
No. pts	154	209	
Median age (range)	62 (27–87)	60 (23–85)	0.21
No. men (%)	94 (61.0)	125 (59.8)	0.81
Median body mass index	30	28	0.62
No. rt kidney (%)	75 (49.0)	122 (58.9)	0.06
No. solitary kidney (%)	13 (8)	11 (5)	0.23
Median mg/dl preop serum creatinine (range)	1.0 (0.4–3.1)	0.9 (0.5–3.4)	0.15
No. baseline renal dysfunction (%)*	20 (13)	16 (7)	0.09
Median cm CT tumor size (range)	3.0 (1.0–7.0)	2.4 (0.7–10.0)	<0.001
No. transperitoneal approach (%)	108 (70.1)	141 (68.1)	0.68
No. pelvicaliceal system repair (%)	154 (100.0)	133 (63.6)	<0.001
Median estimated blood loss (cc)	150	150	0.13
Median mins warm ischemia time (range)	33.5 (0–60)	30.0 (0–68)	<0.001
Median hrs operative time (range)	3.5 (0.8–9)	3 (1.5–7.5)	0.008
Median days hospital stay (range)	2.8 (0.8–3.4)	2.5 (0.9–4.2)	<0.001
Median mg/dl postop serum creatinine (range)	1.2 (0.5–3.7)	1.1 (0.5–2.6)	0.008

* Preoperative serum creatinine greater than 1.4 mg/dl.

blood loss and hospital stay. Urological complications were divided into intraoperative (during surgery), early postoperative (while hospitalized) and late postoperative (following dismissal). Histopathological outcomes were compared.[3] Statistical analyses included the chi-square and Wilcox rank sum tests. All tests were 2-sided with $p < 0.05$ considered statistically significant.

Our technique of LPN incorporating transient en bloc renal hilar control, real-time laparoscopic contact ultrasonography, tumor excision with cold scissors, sutured reconstruction of the pelvicaliceal system and sutured hemostatic renal parenchymal re-approximation has been detailed previously.[4]

RESULTS

A transperitoneal approach was used in 70% of patients with central lesions and in 68% with peripheral lesions. Central tumors were larger on preoperative imaging (median 3.0 vs 2.4 cm, $p < 0.001$) and had larger specimens at surgery (median 43 vs 22 gm, $p < 0.001$) than peripheral tumors (table 1). By definition all 154 patients (100%) in the central group required collecting system entry and suture repair vs 133 (64%) in the peripheral group ($p < 0.001$). Central group cases were associated with longer warm ischemia time (median 33.5 vs 30 minutes, $p < 0.001$), operative time (median 3.5 vs 3 hours, $p = 0.008$) and hospital stay (median 2.8 vs 2.4 days, $p < 0.001$). Although they were statistically significant, these differences did not appear clinically significant. Median estimated blood loss was similar in the 2 groups at 150 cc. Median preoperative serum creatinine was 1.0 and 0.9 mg/dl (normal 0.7 to 1.4) in the central and peripheral groups, respectively. An average of 4.3 and 4.6 months after surgery median postoperative serum creatinine was 1.2 and 1.1 mg/dl, respectively.

TABLE 2. *Pathological features in patients with central and peripheral tumors treated with LPN*

Feature	Central	Peripheral	p Value
No. pts	154	209	
Median specimen wt (gm)	43	22	<0.001
No. pathological findings (%):			
RCC	121 (80.1)	137 (65.5)	0.002
Benign	30 (19.9)	72 (34.5)	
No. T stage (%):			
pT1a	95 (78.5)	122 (89.1)	<0.001
pT1b	18 (14.9)	3 (2.2)	
pT2	1 (0.8)	0 (0.0)	
pT3a	6 (5.0)	12 (8.8)	
pT3b	1 (0.8)	0 (0.0)	
No. grade (%):			
Low	78 (67.2)	91 (71.1)	0.52
High	38 (32.8)	37 (28.9)	
Surgical margin status:*			
Median width (mm)	6	5.8	0.50
No. neg (%)	120 (99.2)	136 (99.3)	
No. pos (%)	1 (0.8)	1 (0.7)	

* In patients with pathologically confirmed RCC.

Table 2 lists the pathological characteristics of the 2 groups. RCC was histologically confirmed in 80% of central and 66% of peripheral tumors ($p = 0.002$). The incidence of margin positivity was 0.8% vs 0.7% in the central and peripheral groups, respectively ($p = 0.5$).

Table 3 lists urological complications in the 2 study groups. The most common intraoperative complication in the central and peripheral groups was hemorrhage (5.2% and 4.8%, respectively). There was 1 open conversion (0.7%) in the central group due to difficulty with clamping the vascular pedicle. One patient in the central group with a normal contralateral kidney underwent laparoscopic radical nephrectomy due to iatrogenic entry into the tumor during LPN. There was 1 ureteral injury (0.5%) in the peripheral group, which was repaired laparoscopically.[4,5]

TABLE 3. *Urological complications in patients with central and peripheral tumors treated with LPN*

Complications	No. Central (%)	No. Peripheral (%)	p Value
Overall	154	209	
Intraop:	8 (5.2)	10 (4.8)	0.86
Hemorrhage + blood transfusion	4 (2.6)	5 (2.4)	
Splenic injury	0	1 (0.5)	
Bowel injury	1 (0.7)	0	
Conversion to open partial nephrectomy	1 (0.7)	0	
Conversion to laproscopic radical nephrectomy	1 (0.7)	0	
Ureteral injury	0	1 (0.5)	
Other	1 (0.7)	3 (1.4)	
Early postop:	9 (5.8)	4 (1.9)	0.05
Hemorrhage + blood transfusion	6 (3.9)	2 (1.0)	
Urine leakage	2 (1.3)	0	
Acute tubular necrosis (hemodialysis)	1 (0.7)	2 (1.0)	
Late postop:	12 (7.8)	16 (7.7)	0.96
Hemorrhage + blood transfusion	5 (3.2)	7 (3.3)	
Urine leakage	3 (1.9)	3 (1.4)	
Arteriovenous fistula	2 (1.3)	4 (1.9)	
Perirenal abscess	0	1 (0.5)	
Acute tubular necrosis (hemodialysis)	2 (1.3)	1 (0.5)	
Reoperation	1 (0.7)	5 (2.4)	0.25

In the central and peripheral groups the most common early postoperative complication was hemorrhage (4% and 1% of cases, respectively). Two patients (1.3%) in the central group and none in the peripheral group had urine leakage. Treatment comprised a ureteral stent in 1 patient and Foley catheter drainage in the other.

Of the late postoperative complications in the central and peripheral groups hemorrhage was again the most frequent one (3.3% and 3.2%, respectively). Two patients (1.3%) in the central group had an arteriovenous fistula requiring angioembolization compared to 4 (1.9%) in the peripheral group. Urine leakage was observed in 3 patients per group (1.9% and 1.4%, respectively). Reoperation was necessary in 1 patient (0.6%) in the central group due to peritonitis secondary to bowel injury and in 5 (2%) in the peripheral group secondary to postoperative bleeding in 4 and to leakage in an ileoileal anastomosis performed during laparoscopic ileal ureter construction in 1.

DISCUSSION

Nephron sparing surgery is now an accepted and even preferred treatment option for small solid renal tumors. While open partial nephrectomy has been the gold standard in this setting, LPN is rapidly gaining popularity with patients and physicians alike. Initially LPN was reserved for patients with a solitary, small, superficial, primarily exophytic solid renal tumor.[6] With increasing laparoscopic experience and proficiency with intracorporeal suturing LPN is now being applied to more complex, infiltrating and larger tumors in appropriately selected patients who are candidates for nephron sparing surgery. However, central tumors represent a significant technical challenge laparoscopically due to the need for complex reconstruction that incorporates collecting system suture repair and parenchymal renorrhaphy. In certain cases this technical complexity may be further amplified by an anatomically difficult tumor location and significant variations in suturing angles.

Several varying definitions of a central tumor have been proposed in the literature and this issue deserves comment. The most restrictive definition in the literature was adopted by Black et al, who defined central tumors as those "completely surrounded by normal parenchyma."[7] Hafez et al defined central tumors as those "extending centrally into the kidney beyond the renal medulla into the renal sinus."[2] Drachenberg et al defined central tumors as those "completely encircled by parenchyma or transgressing the interpapillary line on computerized tomography."[1] Brown et al used the least restrictive criteria, defining central tumors as those located "less than 5 mm from the pelvicaliceal system or hilar vessels."[8] We defined central tumors as those centrally extending into the kidney in direct contact with or invading into the collecting system and/or renal sinus on preoperative 3-D CT. In our study all central tumors were intimately associated with the collecting system and by definition they required entry into the collecting system at resection.

While the difference between the definition of Black at el[7] and that adopted by Brown et al[8] is quite significant, the rest of the definitions are quite similar. The difference between renal tumors that extend beyond the renal medulla into the renal sinus, those that transgress the interpapillary line and those in direct contact with or invading the collecting system and/or renal sinus is minimal at best. Tumors that come in direct contact with or invade the collecting system or renal sinus by definition transgress the interpapillary line and extend beyond the renal medulla.

Given the lack of a strict definition of central tumors as well as the importance of this issue for oncological and clinical outcome analysis, we extend a call for standardization of the definition for future studies. This will undoubtedly facilitate interinstitutional comparisons and data reporting.

While overall outcomes for LPN have been reported previously,[5,9–11] data on LPN for central tumors are limited. Even open partial nephrectomy performed for centrally located tumors is recognized as a technically demanding procedure that is associated with increased complication rates compared to that done for peripherally located tumors.[1,2]

Herein we summarize our experience with LPN for centrally located tumors with an emphasis on operative outcomes and complication rates, and contrast these data with those on LPN for peripheral tumors. Preoperative patient characteristics were similar between the groups. Central tumors in our study were larger than peripheral tumors (3 vs 2.4 cm, $p < 0.001$) and more often malignant on pathological evaluation (80% vs 66%, $p = 0.002$). This relationship between tumor size and histology is consistent with the prior literature showing that smaller lesions are more commonly benign than larger lesions.[12] Intraoperatively there was no difference between the 2 groups in regard to the selected laparoscopic approach and blood loss. However, central tumor location was associated with longer warm ischemia time, operative time and hospital stay. Although these differences were statistically significant, we believe that the clinical significance of a difference of 3.5 minutes of mean warm ischemia time, 30 minutes of mean operative time and 7 hours of mean hospital stay is questionable.

While intraoperative and late postoperative complication rates were virtually identical in the 2 groups, early postoperative complications occurred more commonly in the central group. This difference was secondary to an increased risk of postoperative hemorrhage and urine leakage in this subgroup. This finding is not surprising, given the fact that renal sinus structures (collecting system and larger intrarenal blood vessels) are routinely entered and repaired or controlled in patients with central tumors.

Since the primary emphasis of this study is the technical safety and perioperative outcomes of LPN for central tumors, no attempt was made to assess the oncological outcome in this cohort. As such, a detailed discussion of this issue is beyond the scope of this report. However, local cancer control rates are likely to be similar to those observed in peripherally located tumors since we found no difference in margin positivity between the 2 groups. Only limited data on intermediate term oncological outcome following LPN exist in the literature. While oncological outcomes at 3 years appear promising,[9,11] to our knowledge long-term data are currently lacking.

CONCLUSIONS

LPN for centrally located tumors, which is a technically challenging procedure, requires considerable expertise in minimally invasive surgery. However, it can be performed safely with complication rates that are comparable to

those observed with peripheral tumors. Not unexpectedly surgical management of centrally located tumors is associated with a slightly higher incidence of postoperative hemorrhage and urine leakage. At centers where groups have expertise indications for LPN can be expanded to include centrally located tumors in carefully selected patients.

Abbreviations and Acronyms

3-D	=	3-dimensional
CT	=	computerized tomography
LPN	=	laparoscopic partial nephrectomy
RCC	=	renal cell carcinoma

REFERENCES

1. Drachenberg, D. E., Mena, O. J., Choyke, P. L., Linehan, W. M. and Walther, M. M.: Parenchymal sparing surgery for central renal tumors in patients with hereditary renal cancers. J Urol, **172:** 49, 2004
2. Hafez, K. S., Novick, A. C. and Butler, B. P.: Management of small solitary unilateral renal cell carcinomas: impact of central versus peripheral tumor location. J Urol, **159:** 1156, 1998
3. Fuhrman, S. A., Lasky, L. C. and Limas, C.: Prognostic significance of morphologic parameters in renal cell carcinoma. Am J Surg Pathol, **6:** 655, 1982
4. Gill, I. S., Desai, M. M., Kaouk, J. H., Meraney, A. M., Murphy, D. P., Sung, G. T. et al: Laparoscopic partial nephrectomy for renal tumor: duplicating open surgical techniques. J Urol, **167:** 469, 2002
5. Gill, I. S., Matin, S. F., Desai, M. M., Kaouk, J. H., Steinberg, A., Mascha, E. et al: Comparative analysis of laparoscopic versus open partial nephrectomy for renal tumors in 200 patients. J Urol, **170:** 64, 2003
6. Rassweiler, J. J., Abbou, C., Janetschek, G. and Jeschke, K.: Laparoscopic partial nephrectomy. The European experience. Urol Clin North Am, **27:** 721, 2000
7. Black, P., Filipas, D., Fichtner, J., Hohenfellner, R. and Thüroff, J. W.: Nephron sparing surgery for central renal tumors: experience with 33 cases. J Urol, **163:** 737, 2000
8. Brown, J. A., Hubosky, S. G., Gomella, L. G. and Strup, S. E.: Hand assisted laparoscopic partial nephrectomy for peripheral and central lesions: a review of 30 consecutive cases. J Urol, **171:** 1443, 2004
9. Allaf, M. E., Bhayani, S. B., Rogers, C., Varkarakis, I., Link, R. E., Inagaki, T. et al: Laparoscopic partial nephrectomy: evaluation of long-term oncological outcome. J Urol, **172:** 871, 2004
10. Ramani, A. P., Desai, M. M., Steinberg, A. P., Ng, C. S., Abreu, S. C., Kaouk, J. H. et al: Complications of laparoscopic partial nephrectomy in 200 cases. J Urol, **173:** 42, 2005
11. Moinzadeh, A, Gill, I. S., Finelli, A., Kaouk, J. and Desai, M.: Laparoscopic partial nephrectomy: 3 year follow-up. J Urol, **175:** 000, 2006
12. Frank, I., Blute, M. L., Cheville, J. C., Lohse, C. M., Weaver, A. L. and Zincke, H.: Solid renal tumors: an analysis of pathological features related to tumor size. J Urol, **170:** 2217, 2003