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Abstract

Objective

Laparoscopic partial nephrectomy (LPN) is a technique that is emerging as an attractive option for the treatment of renal tumors ≤4 cm. We retrospectively analyzed our experience with LPN to identify patient and tumor features that correlate with a higher risk of complications.

Material and methods

From January 2001 to May 2007, 90 patients underwent LPN at our institution for a clinically localized renal tumor. A retrospective chart review was carried out. Clinical and pathological information were collected for each patient, including patient age and body mass index, tumor size, location and pattern of growth (cortical vs. corticomedullar), surgical approach (transperitoneal vs. retroperitoneal), warm ischemia time, technique that was used to achieve hemostasis, maximum thickness of the margin of resection, and histology. Statistical analysis (chi-square test, Fisher exact test, Mann-Whitney *U* test, linear regression model) was performed to test the correlation between the above-mentioned variables and the occurrence of complications.

Results

Twenty-two patients (24.4%) had surgical and/or medical complications in our series. The only variable that was found to significantly correlate with a higher number of complications was a corticomedullar tumor growth pattern as opposed to a cortical growth pattern ($p = 0.02$).

Conclusions

LPN is an attractive alternative to open partial nephrectomy for the treatment of small renal tumors. On the basis of our experience, the selection of patients with cortical renal lesions seems to be required to reduce the risk of complications and therefore maximize the advantages of this minimally invasive but challenging procedure.

Keywords

- Laparoscopy;
- Partial nephrectomy;
- Risk factors;
- Complications;
- Renal tumors

1. Introduction

Open partial nephrectomy (OPN) is the current gold standard for the management of ≤ 4 cm, exophytic renal tumors [1] and [2]. The indications are today expanding to include larger and/or deeper renal lesions [3]. Laparoscopic partial nephrectomy (LPN) is emerging as an attractive alternative to OPN [4], but requires advanced laparoscopic skills; therefore, its diffusion is still limited. However, in centers with expertise with minimally invasive surgery, LPN is already the preferred option for treatment of small renal tumors.

The goal of LPN is to completely remove a renal tumor and obtain effective hemostasis of the tumor bed with a short warm ischemia time, in order to ensure minimal morbidity and avoid impairment of renal function. However, there are still concerns about the safety of this procedure. Several studies of LPN have reported postoperative complications in up to 28% of cases, including acute bleeding, delayed bleeding with hematomas, blood transfusions, urine leakage, and renal failure [5] and [6].

The identification of risk factors for complications would allow better patient selection and therefore lower complication rates. In the present study we analyzed our experience with LPN to identify patient and tumor features that correlate with a higher risk of complications.

2. Material and methods

From January 2001 to May 2007, 90 patients underwent LPN at our center for a clinically localized renal tumor. All procedures were performed by the same laparoscopic surgeon (F.P.). All patients had a normal contralateral kidney. Patients with a central or hilar tumor were not eligible for the procedure.

LPN was performed by either a transperitoneal or a retroperitoneal approach. The choice was based on the location of the tumor (transperitoneal approach for anterior and medial lesions, retroperitoneal approach for posterior and lateral lesions). After opening of the Gerota's fascia and identification of the ureter, the renal artery was isolated. The fat surrounding the tumor was preserved. A laparoscopic ultrasound probe was used to better define the anatomy and the edges of the lesion. The renal artery was then clamped with a vascular bulldog, and the resection was carried out with cold scissors. The specimen was immediately placed in an Endocatch® bag, which was then removed at the end of the procedure. Frozen sections of biopsies of the resection bed were obtained only in the presence of surgical suspicion of positive margins (30 of 90 cases). Interrupted 3.0 Vycril® stitches were placed on the renal medulla to obtain hemostasis of the segmentary arteries. The renal parenchyma was then closed with 2.0 Vycril mattress or running sutures. The running suture was locked at both tail ends using Lapra-Ty® or Hem-o-

lock® clips. In 23 cases the use of sealants (Tissucol® and/or Floseal®) was required to improve hemostasis as bleeding was still observed once the suture was completed and the renal artery was unclamped. The sealants were applied directly on the renal breach with the use of a laparoscopic cannula.

A retrospective chart review was carried out. Demographic and clinical information was collected for each patient, including age, gender, and body mass index (BMI). The following tumor characteristics were recorded: side (left or right), location (upper pole, lower pole, mesorenal – defined as tumor in the central third of the kidney, but not involving the renal sinus), pattern of growth at computed tomography (CT) scan (cortical or corticomedullar), volume and maximum diameter at preoperative CT scan, maximum diameter on the surgical specimen, maximum thickness of the margin of resection (healthy parenchyma), histology (benign or malignant), presence of positive surgical margins**.** We defined as cortical tumors those lesions that seemed to involve only the renal cortical at CT scan, whereas all other lesions were considered corticomedullar (Fig. 1).

The surgical approach (transperitoneal vs. retroperitoneal) and the technique used to achieve hemostasis (suture with or without use of sealants) were recorded, as well as operative time, warm ischemia time, blood loss, and preoperative and postoperative serum creatinine levels.

Finally, surgical complications (acute bleeding, hematoma, urine leakage, visceral injuries) and medical complications (renal failure, etc) were collected. Follow-up included serial serum creatinine assessment and abdominal CT scan every 6 mo in the first year after surgery and yearly thereafter. Renal failure was defined as the presence of a serum creatinine level >2 mg/dl.

To evaluate the impact of the learning curve on the risk of complications after LPN, we divided our series into four groups according to the time when the procedure was performed, and we assessed whether there was a significant difference in the complication rate between the four groups.

The statistical analysis was carried out by using the chi-square test, the Fisher exact test, and the Mann-Whitney *U* test for parametric variables. A linear regression model was used to identify a correlation between the precedent variables and the presence of complications. A p value <0.05 was considered statistically significant.

3. Results

No intraoperative complications occurred and no case had to be converted to open surgery. Twenty-two patients (24.4%; 13 males and 9 females) experienced postoperative complications (group A). In this group the approach was transperitoneal in 8 cases and retroperitoneal in 14 cases. The mean age was 53.1 ± 13.9 yr (range, 35–67) and the mean BMI was 24.4 ± 3.1 kg/m^2 (range, 21–30). Eight patients had

right-sided lesions; 14 had left-sided lesions. Eleven tumors were located in the upper pole, 4 were in the lower pole, and 7 were mesorenal. A corticomedullar growth pattern was present in 18 lesions. The mean tumor diameter at preoperative CT scan was 3.13 ± 1.1 cm (range, 2–4.5); the mean CT volume was 34.8 ± 22.4 ml (range, 15–50). Hemostasis was achieved with suture alone in 17 cases, and with suture and sealants in 5 cases. The mean tumor diameter on the specimen was 3.13 ± 1.03 cm (range, 1–6). The thickness of the healthy margin of resection in this group was 7.9 ± 4.9 mm (range, 3–22). Six renal lesions were benign, whereas 16 were malignant. A positive surgical margin was observed in 3 cases. Mean operative time was 120.3 ± 18.6 min (range, 90–125), mean blood loss was 175.7 ± 40.3 ml (range, 80–350), and mean warm ischemia time was 27.4 ± 7.6 min (range, 19–45).

As far as the complications are concerned (Table 3), seven patients had acute bleeding postoperatively. Of these patients, three underwent surgery and three were treated by selective arterial embolization, whereas the last patient was managed conservatively with blood transfusion. Four patients developed perirenal hematomas, which always resolved spontaneously without drainage. Urine leakage was observed in three cases. All cases were treated successfully with ureteral stenting for an average of 30 d. To date, no renal unit was lost and no patient (including those who underwent selective artery embolization for bleeding) developed renal failure during follow-up. Five patients experienced fever over 38 °C, and two patients developed pleuritis (all cases were resolved with antibiotics), whereas one patient had a bowel occlusion due to ileal volvulus on the fourth postoperative day with subsequent need of reintervention. Table 4 provides a detailed analysis of the clinical and pathological characteristics of the patients who had complications.

The clinical and pathological features of the 90 patients overall and after stratification according to the presence (group A) or the absence (group B) of complications are shown in Table 1 and Table 2.

No significant complication was reported in the remaining 68 patients (group B; 42 males and 26 females). In this group the surgical approach was transperitoneal in 30 cases, and retroperitoneal in 38 cases. The mean age in this group was 61.3 ± 12.7 yr (range, 50–79) and the mean BMI was 26.7 ± 2.4 kg/m^2 (range, 23–29). Thirty-six patients had a right-sided lesion, and 32 patients had a left-sided lesion. Twenty-eight tumors were located in the upper pole, 14 were in the lower pole, and 16 were mesorenal. The growth pattern was corticomedullar in 38 cases and cortical in 30 cases. The mean tumor diameter at preoperative CT was 3.16 ± 1.07 cm (range, 1–5); the mean tumor volume at CT was 33.8 ± 15.2 ml (range, 14–47). Hemostasis was achieved with suture alone in 50 cases, and with suture and sealants in 18 cases. The mean tumor diameter on the surgical specimen was 3.11 ± 1.02 cm (range, 1–5.5). The

thickness of the margin of resection was 7.5 ± 3.9 mm (range, 2–15). Eighteen lesions were histologically benign, whereas 50 were malignant.

A positive surgical margin was observed in one case. Mean operative time was 118.6 ± 16.7 min (range, 90–130), mean blood loss was 186.2 ± 31.3 ml (range, 50–500), and mean warm ischemia time was 26.9 ± 8.5 min (range, 18–51).

To evaluate whether the learning curve had an impact on the complication rate, we divided the patients into four chronological groups (1–20, 21–40, 41–60, and 61–90, respectively). Two complications occurred in the first group of patients (one urine leakage, one acute bleeding), five in the second group (one hematoma, one acute bleeding, two high fevers, one urine leakage), six in the third group (two cases of pleuritis, two hematomas, two acute bleedings), and nine in the last group (one urine leakage, three high fevers, three acute bleedings, one hematoma, one bowel occlusion) (Table 5). No significant differences were observed in the complication rate between these four groups ($p > 0.05$).

At univariate analysis, only tumor growth pattern (cortical vs. corticomedullar) was found to correlate with the occurrence of complications, with a significantly higher rate of complications for corticomedullar lesions ($p = 0.02$) (Table 1 and Table 2).

4. Discussion

OPN is today the standard treatment for ≤ 4 cm, exophytic renal tumors. LPN is already the preferred option in centers with advanced laparoscopic expertise. Several large series of LPN have been published and more than 1100 cases have been reported in the literature [4], [5], [6], [7], [8], [9], [10], [11] and [12]. However, the major urological associations' guidelines do not yet consider LPN as the primary choice for treatment of small renal tumors [1] because of the relatively short follow-up of the available series, which does not allow one to draw conclusions on the long-term oncological outcomes, and because of the longer warm ischemia time compared with OPN and the reported high rate of complications [5], [6], [13], [14], [15] and [16]. The complication rate in the largest series of LPN ranged from 10% to 25%, including acute bleeding, urine leakage, hematomas, and renal failure [5], [8], [9], [12], [13], [14], [15], [17] and [18] (Table 6). Experienced centers, such as the Johns Hopkins Hospital and the Cleveland Clinic, recently reported a 28% and 18% complication rate after LPN, respectively [6] and [15]. In a recent review of the complications of 2775 laparoscopies, LPN was found to be the procedure with the second highest complication rate at 28% [6]. However, a review of the literature shows that OPN also has a significant risk of complications, although lower than LPN [19], [20], [21], [22], [23], [24], [25], [26] and [27] (Table 7).

In the present study clinical, surgical, and pathological features of 90 consecutive cases of LPN were assessed to identify predictors of a higher risk of complications. We had no intraoperative issues or conversions to open surgery. Twenty-two patients (24.4%) experienced postoperative medical and/or surgical complications. Only tumor growth pattern was found to correlate with the number of complications, with a significantly lower complication rate for cortical tumors as opposed to corticomedullar tumors ($p = 0.02$). Venkatesh et al [14] have already observed a statistically significant higher risk of complications for deeper or hilar lesions compared with exophytic lesions. However, the results of this study are not comparable with ours because two different classifications of the tumor growth pattern were adopted. Furthermore, seven different surgeons were involved in the study by Venkatesh et al, which may represent a bias.

All other clinical, surgical (approach and need to suture the collecting system) and pathological variables were not found to correlate significantly with the occurrence of complications. The use of sealants was expected to reduce the risk of bleeding and hematomas, as suggested by other recent reports [4] and [28]. In fact, we had only one significant acute bleeding with the use of sealants, but there was not a significant difference in the overall complication rate compared with suture alone.

Tumor side was not found to correlate with a higher risk of complications. However, the absolute number of complications was higher for left-sided tumors. In fact, a left LPN may be more challenging, especially if performed with a transperitoneal approach.

A thicker rim of healthy parenchyma resected with the tumor was also expected to correlate with a higher risk of complications because of injuries to the collecting system and deeper vessels. However, the maximum thickness of the surgical margin is not a reliable indicator of the surgical risk, likely because it mostly depends on the location of the tumor in relation to the surgical instruments rather than on the depth of the tumor growth in the renal parenchyma.

Furthermore, tumor size surprisingly does not correlate with complications. This confirms that the growth pattern is the most important indicator of surgical risk. In fact, a smaller tumor with corticomedullar growth likely has a risk of complications similar to that of a larger cortical tumor that is mostly exophytic.

As far as the learning curve is concerned, one may expect a reduction in the complication rate with increasing experience. However, once again, we did not observe this reduction in our series. Conversely, we had a higher number of complications in the last group of patients we operated on (Table 5). This may be due to the fact that surgeons tend to select easier cases in the first part of the learning curve, thereby limiting the risk of complications, whereas the number of challenging cases increases with growing experience. In fact, 19 of the first 20 cases of our series were cortical tumors. Conversely, in the Cleveland Clinic experience the complication rate seems to be declining over time owing to the increasing experience of the surgeon, the standardization of the technique, and the use of hemostatic sealants, such as Floseal, which has resulted in a significant reduction in acute bleeding [4]. However, the reduction in the complication rate in this series became significant only after a very large number of procedures (>200) in a center that is dedicated mainly to minimally invasive treatment of renal tumors. Therefore, we may not have been able to observe this trend in our series because we did not reach such a volume of

procedures. This confirms that LPN is a challenging technique that requires a very long learning curve to significantly improve its safety.

In summary, on the basis of our results, it seems that the selection of patients with cortical tumor for LPN can minimize the risk of complications. In fact, the most important predictor of complications is the tumor growth pattern. However, larger series are needed to further define which patients diagnosed with small renal tumors can benefit from this minimally invasive procedure with the minimal risk of morbidity.

5. Conclusions

LPN is an attractive option for treatment of small renal tumors, but there are still concerns about its safety. On the basis of our findings, cortical renal tumors have a significantly lower complication rate compared with tumors with a corticomedullar growth pattern. Therefore, accurate selection of patients for LPN is important to maximize the results of this minimally invasive but challenging procedure.

Conflicts of interest

The authors have nothing to disclose.

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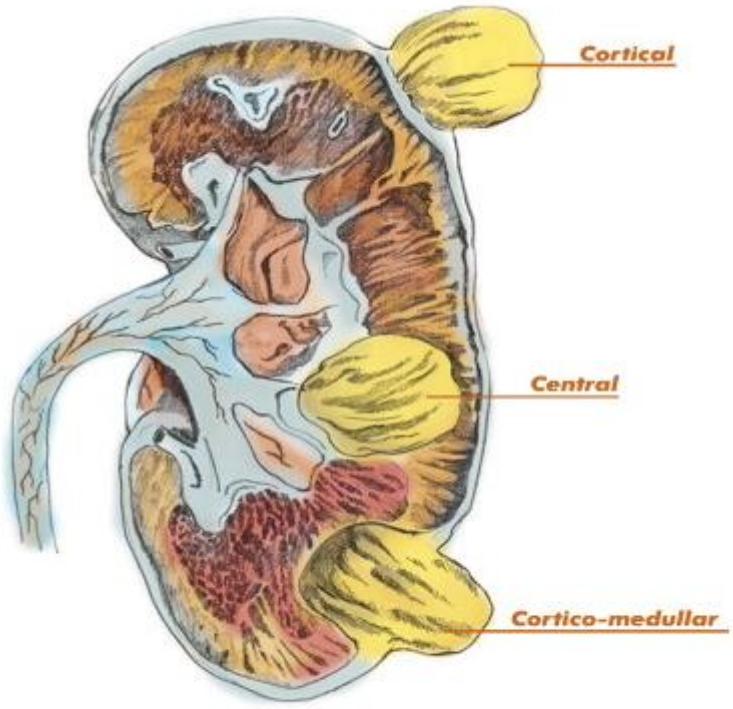

Fig. 1.

Classification of renal tumors according to location.

Table 1.

Clinical and pathological features of patients overall and stratified by group (group A = postoperative complications; group B = no postoperative complications)

	All patients	Group A (complications)	Group B (no complications)	*p*
Patients	90	22 (24.4%)	68 (76.6%)	
Mean age (yr) ± SD (range)	56.3 ± 13.5 (35–79)	53.1 ± 13.9 (35–67)	61.3 ± 12.7 (50–79)	ns
Mean BMI (kg/m^2) ± SD (range)	24.6 ± 2.9 (21–30)	24.4 ± 3.1 (21–30)	26.7 ± 2.4 (23–29)	ns
Mean preoperative serum creatinine (mg/dl) ± SD (range)	1.1 ± 0.3 (0.8–1.2)	1.1 ± 0.4 (0.8–1.2)	1.1 ± 0.3 (1–1.2)	ns
Tumor side				ns
Right	44	8	36	
Left	46	14	32	
Tumor location				ns
Upper pole	39	11	28	
Mesorenal	23	7	16	
Lower pole	18	4	14	
Tumor growth pattern				0.02
Corticomedullar	6	18	38	
Cortical	34	4	30	

Mean CT tumor diameter (cm) ± SD (range)	3.12 ± 1.02 (1–5)	3.13 ± 1.1 (2–4.5)	3.16 ± 1.07 (1–5)	ns
Mean surgical tumor diameter (cm) ± SD (range)	3.09 ± 1.04 (1–6)	3.13 ± 1.03 (1–6)	3.11 ± 1.02 (1–5.5)	ns
Mean CT tumor volume (ml) ± SD (range)	34.3 ± 18.6 (15–55)	34.8 ± 22.4 (15–50)	33.8 ± 15.2 (14–47)	ns
Maximum thickness of the surgical margin (mm) ± SD (range)	7.6 ± 4.2 (2–22)	7.9 ± 4.9 (3–22)	7.5 ± 3.9 (2–15)	ns
Tumor histology				ns
Benign (oncocytoma, angiomyolipoma, etc)	24	6	18	
Malignant	66	16	50	
Clear-cell RCC	37	10	27	
Papillary RCC	19	4	15	
Other	10	3	7	

SD, standard deviation; ns, not statistically significant ($p > 0.05$); BMI, body mass index; CT, computed tomography, RCC, renal cell carcinoma.

Table 2.

Surgical features overall and stratified by group (group A = postoperative complications; group B = no postoperative complications)

	All patients	Group A (complication)	Group B (no complication)	*p*
Surgical approach				ns
Retroperitoneal	52	14	38	
Transperitoneal	38	8	30	
Operative time (min) ± SD (range)	116.6 ± 26.6 (90–130)	120.3 ± 18.6 (90–125)	118.6 ± 16.7 (90–130)	ns
Blood loss (ml) ± SD (range)	183 ± 35.7 (50–500)	175.7 ± 40.3 (80–350)	186.2 ± 31.3 (50–500)	ns
Warm ischemia time (min) ± SD (range)	27.1 ± 9.7 (18–51)	27.4 ± 7.6 (19–45)	26.9 ± 8.5 (18–51)	ns
Mean postoperative (24 h) serum creatinine (mg/dl) ± SD (range)	1.09 ± 0.6 (0.9–1.5)	1.06 ± 0.5 (0.9–1.3)	1.2 ± 0.6 (1–1.5)	ns
Suture of the collecting system	9	5	4	ns
Hemostatic technique				ns
Suture + sealants	23	5	18	
Suture alone	67	17	50	

ns, not statistically significant ($p > 0.05$).

Table 3.

Surgical and medical complications

Intraoperative complications	None
Medical complications	5 fevers
	2 pleuritis
Surgical complications	7 acute bleedings
	4 hematomas
	3 urinary leakages
	1 bowel occlusion

Table 4.

Clinical and pathological characteristics of the cases with complications

	Acute hemorrhage surgery (3)	Acute hemorrhage embolization (3)	Urine leakage (3)	Hematomas (4)
Upper pole tumors (7)	2	1	2	2
Mesorenal tumors (3)	0	0	1	2
Lower pole tumors (3)	1	2	0	0
Corticomedullar tumors (10)	2	3	2	3
Cortical tumors(3)	1	0	1	1
Benign tumors (5)	2	1	1	1
Malignant tumors(8)	1	2	2	3
Hemostasis with suture alone (11)	3	2	2	4
Hemostasis with suture and sealants (2)	0	1	1	0

Table 5.

Distribution of complications during the learning curve

	Complications	Growth pattern
Patient 1–20	2/20	19 cortical
	1 urinary leakage	1 corticomedullar
	1 acute bleeding	
Patient 21–40	5/20	3 cortical
	1 urinary leakage	17 corticomedullar
	1 acute bleeding	
	1 hematoma	
	2 high fevers	
Patient 41–60	6/20	6 cortical
	2 acute bleedings	14 corticomedullar
	2 hematomas	
	2 cases of pleuritis	
Patient 61–90	9/30	6 cortical
	1 urinary leakage	24 corticomedullar
	3 acute bleedings	
	1 hematoma	
	3 high fevers	
	1 bowel occlusion	

Table 6.

Intra- and postoperative complications in the published series of laparoscopic partial nephrectomy

	Procedures	Intraoperative complications	Postoperative complications	Complication rate
Seifman et al [5]	40	0%	25%	25%
Link et al [8]	217	3.2%	6.9%	10.1%
Kim et al [9]	79	6.3%	3.8%	10.1%
Weld et al [12]	60	0%	11.6%	11.6%
Abukora et al [13]	78	3.6%	6.4%	10.3%
Venkatesh et al [14]	123	0.4%	12%	12.4%
Ramani et al [15]	200	3.5%	14.5%	18%
Bermudez et al [17]	28	7.15%	7.15%	14.3%
Albqami et al [18]	78	3.8%	10.7%	14.5%

Table 7.

Complication rates in the published series of open partial nephrectomy

Author	Cases	Mean tumor size (cm)	Complications
Marberger (1983) [19]	72	—	17%
Van Poppel (1991) [20]	76	0.9–15	10%
Moll (1993) [21]	105	—	9.5%
Campbell (1994) [22]	259	—	30%
Polascik (1995) [23]	67	—	38%
Belldegrun (1999) [24]	146	3.6	5.5%
Shekarriz (2002) [25]	60	3.8	10%
Fergany (2006) [26]	400	4.18	13%
Patard (2007) [27]	1048	3.4	12.5%