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EVOLUTION OF SURGICAL TECHNIQUE AND PATIENT OUTCOMES FOR LAPAROSCOPIC PARTIAL NEPHRECTOMY

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ABSTRACT

Objectives. To review the operative technique, complication rates, and short-term oncologic efficacy of the first 60 laparoscopic partial nephrectomies performed by a single surgeon and to report changes in our technique and the associated outcomes.

Methods. Between January 2002 and December 2004, data regarding patient characteristics, intraoperative technique, and outcome of 60 consecutive patients undergoing laparoscopic partial nephrectomy were prospectively collected.

Results. All 60 procedures were successfully completed laparoscopically without conversion to an open or hand-assisted approach. Histopathologic examination revealed renal cell carcinoma in 60% of patients with no positive margins or recurrences at a mean follow-up of 25.3 months. The overall complication rate was 30.0%, with 8 urologic (13.3%) and 10 nonurologic (16.7%) complications.

Conclusions. With experience, laparoscopic partial nephrectomy is a viable alternative to open partial nephrectomy for small renal masses. At present, energy technologies and surgical pharmaceuticals are helpful adjuncts, but are not reliable for primary hemostasis and collecting system closure. Adaptation of traditional open techniques, including vascular control, excision of the tumor with cold scissors, and suture reconstruction of the collecting system and parenchyma, remain necessary to consistently perform laparoscopic partial nephrectomy successfully. UROLOGY **67:** 502–507, 2006. © 2006 Elsevier Inc.

Laparoscopic partial nephrectomy (LPN) was first reported in 1993 by Winfield and colleagues[1] and McDougall and coworkers.[2] Soon thereafter, the initial laparoscopic retroperitoneal partial nephrectomy was reported by Gill and colleagues.[3] Several series have documented results attesting to the short-term success of oncologic control of LPN.[4–7] Recently, Gill and colleagues[8] compared their experience with 100 LPNs with their experience with 100 open partial nephrectomies, with excellent results. However, laparoscopic nephron-sparing surgery continues to present unique challenges regarding reconstruction of the collecting system and renal parenchymal defects.[9] To date, novel surgical pharmaceuticals, energy-based instruments, and techniques have been suggested to facilitate LPN.[10–14]

As such, we report a single-surgeon experience with 60 LPNs performed during a 3-year period to evaluate the evolution in our technique and the associated surgical outcomes. Specifically, complications and lessons learned in relation to the techniques of hemostasis and renal parenchymal reconstruction are presented.

MATERIAL AND METHODS

After approval from the institutional human studies review board, data were collected from patients who underwent LPN for treatment of renal masses from January 2002 through December 2004. Each patient underwent counseling regarding the benefits and associated challenges, with all surgical options, including open and laparoscopic radical surgery, watchful waiting, open partial nephrectomy, ablative technologies, and LPN, discussed. Each patient underwent a traditional staging evaluation to exclude metastatic disease. A postoperative follow-up regimen was specifically designed for this study and included postoperative computed tomography or magnetic resonance imaging and serum evaluation at 6, 12, and 18 months and annually thereafter.

The collected data included patient characteristics, preoperative imaging, intraoperative techniques and technologies applied during the procedure, tumor characteristics, postop-

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TABLE I. *Patient and tumor characteristics*

Patient Group	Patient Characteristics: Mean Age (yr)	Sex (n): M	Sex (n): F	Tumor Characteristics: Location (n): Exo	Meso	Endo	Hil	Mean Diameter (cm)	Cystic Component (n)
1	58.5 (39–76)	4	6	3	3	3	1	1.7 (0.7–2.5)	4
2	53.1 (39–61)	6	4	3	5	2	0	1.8 (1.4–3.4)	2
3	57.6 (35–77)	4	6	3	4	1	2	2.9 (1.5–4.6)	3
4	55.1 (35–68)	7	3	5	2	2	1	3.1 (1.8–5.1)	5
5	56.2 (44–73)	5	5	5	3	2	0	2.2 (1.5–3.3)	1
6	57.5 (37–78)	5	5	3	2	3	2	2.7 (1.0–5.0)	3

KEY: M = male; F = female; Exo = exophytic; Meso = mesophytic; Endo = endophytic; Hil = hilar.
Data in parentheses are ranges.

TABLE II. *Surgical technique*

Patient Group	Approach: Trans	Approach: Retro	Laparoscopic Ultrasound	Artery Clamped	Mean Ischemic Time (min)	Resection Tool (n): FB, Harmonic	Resection Tool (n): Cold Scissors	Collecting System Entry (n)
1	9	1	8	2	25.5 (20–31)	10	0	1
2	8	2	7	4	33.5 (28–44)	9	1	2
3	4	6	4	9	25.7 (16–37)	2	8	6
4	9	1	10	10	27.3 (10–39)	0	10	4
5	7	3	10	9	24.4 (10–36)	2	8	5
6	6	4	10	10	25.0 (13–32)	0	10	5

KEY: Trans = transperitoneal; Retro = retroperitoneal; FB = Floating Ball.
Data in parentheses are ranges.

erative convalescence, and complications. To quantitate the level of difficulty of each LPN procedure optimally, the tumors were characterized as exophytic, endophytic, mesophytic, or hilar, as described by Finley and colleagues.[15] Specifically, tumors in which more than 60% of the circumference of the tumor on cross-sectional imaging extended beyond the natural border of the kidney were considered exophytic. Tumors in which more than 60% of the tumor was within the natural border of the kidney were considered endophytic. All remaining tumors were characterized as mesophytic. If tumors were located within 5 mm of the main renal artery or vein, they were classified as hilar.

The technical considerations for each LPN were documented. Specifically, the mechanism of parenchymal transection, application of hemostatic energy sources, application of surgical pharmaceuticals, need and type of collecting system closure, and type of parenchymal closure were documented.

A negative surgical margin was defined as normal renal parenchymal tissue surrounding the renal lesion in all dimensions on primary excision. A urine leak was strictly defined as continued urine output from the drain after postoperative day 2. Suspicion of a urine leak was confirmed by checking the creatinine level of the fluid collected from the drain after postoperative day 2. If a urine leak was confirmed, the patient was taken for retrograde pyelography and ureteral stent placement. A blood loss complication was defined as the need for transfusion or an estimated blood loss of greater than 1000 mL.

RESULTS

The patient data were organized into six groups of 10 patients each according to the chronologic order of the procedure date. Table I lists the patient and tumor characteristics by patient group. The mean patient age was 56.3 years (range 35 to 78). Of the 60 tumors, 22 (36.7%), 19 (31.7%), 13 (21.7%), and 6 (10.0%) were exophytic, mesophytic, endophytic, and hilar, respectively. The mean tumor diameter was 2.4 cm (range 0.7 to 5.1).

Table II summarizes the surgical techniques for each procedure in chronologic order. Of the 60 tumors, 43 (71.7%) were approached using a transperitoneal route, and laparoscopic ultrasonography was used in 49 cases (81.7%). The renal artery was clamped in 44 patients (73.3%), with a mean ischemic time of 26.9 minutes (range 10 to 44). Intrarenal cooling was performed in five procedures, as previously described.[16] The intrarenal cooling technique was used in patients in whom the surgeon anticipated a prolonged ischemic time, as determined by preoperative imaging. The mean ischemic time for these procedures was 39 minutes (range 28 to 50). Owing to the tumor location, 8 patients underwent preoperative ureteral stenting because of anticipated collecting system violation. Despite the challenging location of these hilar or endophytic tumors, none of the cases performed with a ureteral catheter and subsequent collecting system decompression with a double-J stent were complicated by a urine leak.

Table III summarizes the hemostatic and reconstructive techniques, and Table IV shows the postoperative results for the sequential patient groups. The overall complication rate was 30.0%, with a urologic complication rate of 13.3% (five urine

TABLE III. ***Hemostatic/reconstructive techniques***

Patient Group	FB	Argon Beam	Bipolar	Fibrin Glue	Suture	Surgicel Bolster	FloSeal
1	5	7	4	8	4	2	0
2	8	2	1	7	1	3	0
3	9	0	0	8	5	5	1
4	9	0	0	5	7	6	1
5	10	0	0	6	9	10	6
6	10	0	0	0	10	10	10

KEY: FB = Floating Ball.

TABLE IV. ***Postoperative results***

Patient Group	Mean OR Time (min)	Complications (n)		Malignant (n)	Mean Negative Margin (mm)	RCC Grade		Mean EBL (mL)	Mean HDs (range)
		Leak	Hemorrhage			Low	High		
1	170 (70–225)	1	0	6	3.7 (1–7)	5	1	174 (50–500)	2.6 (1–4)
2	181 (120–300)	0	1	6	2.3 (1–5)	6	0	290 (50–1000)	2.1 (1–4)
3	194 (110–339)	3	1	6	3.3 (2–5)	4	2	248 (30–1100)	3.5 (1–7)
4	186 (150–215)	1	0	5	5.3 (2–11)	5	0	263 (50–800)	2.6 (1–4)
5	157 (65–215)	0	0	7	3.3 (1–7)	7	0	208 (15–450)	3.1 (2–5)
6	188 (130–420)	0	0	6	6.2 (1–12)	5	1	170 (50–300)	2.5 (1–4)

KEY: OR = operative time; RCC = renal cell carcinoma; EBL = estimated blood loss; HDs = hospital days.
Data in parentheses are ranges.

leaks, two hemorrhages, and one lower urinary tract infection). Despite offering conservative options, the second patient in the series requested completion radical nephrectomy because of persistent urine leak after 1 week. All other patients with urine leaks were successfully treated in a conservative fashion with ureteral stent placement and prolonged perirenal drainage. Hemorrhage occurred in 2 patients, with 1 requiring postoperative blood transfusion. The patient who required a blood transfusion was later identified to have a bleeding disorder that had not been appreciated by the patient or surgeon preoperatively. No patients experienced delayed bleeding. No patient scheduled for LPN required conversion to radical nephrectomy. No conversions were required from the laparoscopic approach to an open or hand-assisted procedure. The nonurologic complication rate was 16.7% (3 cases of fever/atelectasis, 2 of prolonged ileus, 2 of wound infection, 1 of deep venous thrombosis, 1 of pleural effusion, and 1 of congestive heart failure).

In each case, after parenchymal transection, the specimen was sent for frozen section analysis and evaluated in every dimension for a negative surgical margin by taking multiple thin slices. In all cases, frozen section histopathologic examination demonstrated a negative margin, and no patient required resection of additional tissue or completion nephrectomy because of a positive margin. No patients were excluded from the current study. Thirty-six patients (60%) had malignant pathologic findings with clear cell carcinoma (77.8%) and papillary (16.7%) carcinoma as the most common histologic types. All 60 patients had negative tumor margins on final histopathologic examination. The minimal tumor margin (closest distance from tumor to the resection margin) averaged 3.0 mm in the first 30 LPNs and the average minimal tumor margin was 4.7 mm in the latter half of the procedures. Twenty-four patients (40%) had benign pathologic findings with Bosniak type III complex cystic disease (45.8%), angiomyolipoma (29.2%), and oncocytoma (12.5%) as the most common subtypes. Of the patients with complex cystic disease, care was taken to resect and entrap the cystic mass without fluid spillage.

COMMENT

Consistent efforts to improve our technique for LPN included changes to minimize the risk of positive margins, bleeding complications, and urine leakage. These efforts have resulted in a continued evolution of our routine approach to LPN.

In the course of the series, we documented an increasing reliance on laparoscopic ultrasound evaluation of the kidney. Later in the series, the duplex ultrasound features of the laparoscopic ultrasound device were also incorporated into our standard technique. Starting with patient 28, all tumors underwent laparoscopic ultrasound imaging. Laparoscopic ultrasonography was used to expedite tumor identification. Ultrasound identifica-

tion of smaller masses was particularly useful in patients with a large amount of perinephric adipose tissue. Laparoscopic ultrasonography was also particularly useful to help the surgeon determine an adequate margin of parenchymal transection. Once comfort was achieved with the laparoscopic ultrasound probe, the duplex feature was used to confirm complete interruption of the arterial blood supply to the area surrounding the tumor after arterial clamping. On two occasions, inadequate hilar clamping was identified and corrected before parenchymal transection by application of the duplex ultrasound feature.

The increasing dependence on laparoscopic ultrasonography was likely primarily based on increasing surgeon comfort and skill with application of the technology. Although no change in margin status resulted during the course of the series, the cases performed were increasingly challenging and the minimal negative surgical margin distance increased. As such, it is our firm belief that application of laparoscopic ultrasound imaging can help minimize the risk of positive margins and bleeding complications.

During our series, an increased tendency occurred for transient arterial control during parenchymal transection. The improved vision provided by temporary selective or main renal arterial occlusion justifies the risks of a reasonably short warm ischemia time. Parenchymal transection in a bloodless field reduces the dependence on the application of energy devices. Cold scissor parenchymal transection expedited tumor excision without the tissue charring associated with energy-based tools. Without charring, visual confirmation of the plane of parenchymal transection to ensure an adequate tissue margin is possible. Early in this series, the operating team was heavily dependent on energy devices such as the argon beam coagulator and the Floating Ball device (TissueLink, Dover, Mass). These devices were useful for small exophytic tumors, but they did not provide complete and reliable hemostasis in all cases. As such, to minimize the risk of a positive margin or bleeding complication, we modified our technique to incorporate hilar control for most renal masses.

Additionally, during the series, the average resection margin increased by 1.7 mm. We believe the increase in the precision of our minimal tumor margin was partially the result of better vision with hilar clamping and better understanding of the target anatomy as delineated by laparoscopic ultrasonography.

Pruthi and colleagues[12] found fibrin glue helpful because of its hemostatic and sealant properties during LPN. We observed lower blood loss with the application of a dedicated hemostatic pharmaceutical (FloSeal) rather than fibrin glue. The most successful combination of technique with pharmaceutical aids to minimize blood loss included application of FloSeal to the resection bed, with subsequent suture closure of parenchyma over bolsters. Additionally, exclusion of fibrin glue from our technique in the more recent procedures did not result in increased bleeding or leakage.

During our series, the most challenging complication we experienced was urine leakage. Most urine leaks occurred in patients with hilar tumors. As a result of problems with urine leakage in patients with hilar tumors, we have recently altered our technique for these challenging cases to include preoperative placement of an external ureteral stent.[17] During the procedure, retrograde injection of sterile saline through the stent allows for precise identification and suture reconstruction of the collecting system. Since incorporating this change, we have performed five LPNs for hilar tumors without leakage.

We found that the use of TissueLink, FloSeal, and Surgicel bolsters and placing hemostatic sutures in the tumor resection bed were associated with less blood loss. We observed a greater estimated blood loss with argon beam and fibrin glue use. The argon beam coagulator and fibrin glue themselves were likely not responsible for the increased blood loss. We believe that increased reliance on energy devices and surgical pharmaceuticals was responsible for the increased blood loss. Although these adjunctive technologies may be helpful, they cannot routinely provide adequate hemostasis for cases in which significant parenchymal transection is performed. As such, the decreased blood loss later in our series was likely the result of better simulation of the open technique, including parenchymal suturing over absorbable bolsters.

During hilar dissection, we typically identified multiple segmental arteries to the kidney. Depending on the intrarenal tumor location, we have successfully sacrificed or temporarily occluded segmental arteries, with the advantage of not subjecting the entire kidney to the risks associated with warm ischemia. In these cases, duplex ultrasound evaluation of the surrounding renal parenchyma is required to determine whether segmental artery control will result in adequate localized transient parenchymal ischemia. If the tumor is not amenable to selective arterial clamping, we routinely clamp the main renal artery during LPN.

Regarding energy devices, we routinely now use the Floating Ball device in the resection bed renal cortex after clamping the renal artery. This technique is very different from the initial description of Floating Ball application by Sundaram and colleagues.[14] In their, and all subsequent, series de-

scribing the application of the Floating Ball for partial nephrectomy, the device has been used to precoagulate renal tissues before transection. In contrast, our current technique depends on application of the Floating Ball device after cold cutting through the renal parenchyma. We have found excellent hemostasis can be achieved using the Floating Ball and FloSeal as adjuncts only to parenchymal suturing.

Despite the utility of novel devices and surgical pharmaceuticals, our technique has evolved to simulate the traditional open technique, with transient arterial control followed by cold tumor excision. Suture repair of the collecting system and parenchymal defect are critical steps to open partial nephrectomy and LPN. Application of the Floating Ball device and FloSeal remain helpful adjuncts but cannot be depended on for reliable hemostasis.

CONCLUSIONS

The technique of LPN has evolved significantly. Laparoscopic ultrasonography and duplex ultrasound technology are very useful for minimizing the risk of positive surgical margins. Although currently available technologies remain useful adjuncts, only simulation of the steps of open surgery has allowed for consistent results regarding hemostasis and collecting system closure.

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EDITORIAL COMMENT

This paper is another building block in the accumulating evidence that laparoscopic partial nephrectomy in experienced hands is successfully developing as a standard of care for the surgical management of renal tumors. The authors nicely describe the evolution of their method for laparoscopic partial nephrectomy (LPN), providing the rationale and experience that led to these modifications in surgical techniques and the use of biologic sealants. It is obvious that even in their skilled hands after 60 cases, the procedure is still evolving and is still being defined. Similar experiences from multiple institutions with related modifications are constantly being reported, representing the intense quest by proficient laparoscopic surgeons for the best way to perform LPN. In the heat of this quest, patients with tumors greater than 4 cm, single kidneys, and compromised renal function have been included in the initial cohorts of LPN. A word of caution is warranted.

Urologic laparoscopic surgeons are not only in the midst of the learning curve, but are still in the invention curve for LPN. Gill's group from the Cleveland Clinic is leading this effort. They have accumulated an experience of more than 500 LPNs and are still exploring the best approach and limitations to LPN. Consensus is evolving regarding the need for complete hilar clamping, cold scissor excision of the tumor, and meticulous suturing of the collecting system and renal parenchyma. The debate regarding the best use of energy for tissue coagulation and biologic sealants is ongoing; however, the outcomes with the different modalities have been acceptable. Patient selection remains the only area that may undermine our responsible application of LPN.

At this point, even in the best of hands, LPN should be limited to tumors less than 4 cm that are not hilar and are in patients with a normal contralateral kidney and normal renal function.

These reservations stem from two reasons. First, long-term cancer control outcomes for tumors greater than 4 cm that are managed by partial versus radical nephrectomy are as yet unproven. Second, no method is yet available for efficient laparoscopic renal cooling that can match the level of renal hypothermia achieved with ice slush during open partial nephrectomy.

Judgment of long-term cancer control when partial versus radical nephrectomy is performed for tumors greater than 4 cm should be based on the reference standard open partial nephrectomy with renal cooling. This comparison is currently underway in multiple tertiary centers, and data are rapidly accumulating. Only if open partial nephrectomy is proven to have equivalent long-term cancer control as that for radical nephrectomy for tumors greater than 4 cm, should LPN be used for these larger tumors.