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CHAPTER 2

LAPAROSCOPIC PARTIAL NEPHRECTOMY: CONTEMPORARY TECHNIQUE AND OUTCOMES

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ABSTRACT

Objectives

Laparoscopic partial nephrectomy (LPN) has emerged as a viable alternative to open partial nephrectomy while minimizing patient morbidity. In this article, we describe our current technique of LPN and review our outcomes in specific patient sub-sets.

Methods

Since September 1999, more than 500 LPNs have been performed by the senior author. Data were collected prospectively. All patients underwent a three-dimensional CT scan prior to the operation. Our established technique involves preoperative ureteral catheterization, laparoscopic renal ultrasonography to delineate the tumor, en bloc clamping of the renal hilar vascular pedicle, tumor excision with cold endoshears, pelvicaliceal suture repair and parenchymal closure over Surgicel bolsters with biologic hemostatic agent. Renal hypothermia was achieved laparoscopically with ice slush in selected cases with anticipated long warm ischemia time.

Results

Mean tumor size was 2.9 cm (1-10.3 cm), 31% of the tumors were greater than 3 cm, 5% occurred in a solitary kidney, and tumor location was central in 40% and hilar in 6% of patients. Transperitoneal approach was employed in 65% of the cases. Mean warm ischemia time was 32 minutes. Intraoperative complications occurred in 5.5%. Pathology confirmed renal cell carcinoma in 75% of the tumors. In the initial 100 patients with a 3 years minimum follow-up, overall survival was 86% and cancer-specific survival was 100%.

Conclusions

Laparoscopic partial nephrectomy is a technically challenging procedure. Adequate prior experience with laparoscopy is necessary. Long-term functional and oncological outcomes are being confirmed currently.
INTRODUCTION

Widely available radiographic imaging has led to increased detection of incidental small renal lesions. Open partial nephrectomy offers long-term oncological outcomes equivalent to that of radical nephrectomy and long-term preservation of renal function in selected patients with small renal tumor [1]. Laparoscopic partial nephrectomy (LPN) has emerged as a viable alternative to open partial nephrectomy while minimizing patient morbidity [2]. In the beginning, LPN was limited to patients with a small, superficial, solitary, peripheral, exophytic tumor. However, with increasing laparoscopic experience, the indications of LPN have been carefully expanded to include larger, central, hilar and infiltrating tumors. In this article and accompanying video we describe our established technique of LPN and review our intermediate-term outcomes.

MATERIALS AND METHODS

Since September 1999, more than 500 laparoscopic partial nephrectomy have been performed by us. Demographic data, past medical history, preoperative functional and imaging data, intraoperative data, complications, pathology results and follow-up data were collected prospectively in a secured database with Institutional Review Board approval.

Our technique of LPN aims to duplicate established oncological principles underlying the open technique [2]. All patients underwent a spiral CT scan with 3-mm sections and 3-dimensional video reconstruction at the Cleveland Clinic prior to the operation. This CT scan provides information regarding tumor size, location, extent of parenchymal infiltration, proximity to the pelvicaliceal system and defines the renal vasculature, with details regarding the number, location, anomalies, and spatial interrelationships of the renal arteries and veins. The choice of the laparoscopic approach is dictated by the location and the technical complexity of the renal mass. Anterior, anterolateral and lateral tumors are preferentially approached transperitoneally. Posterior, posteromedial and posterolateral tumors are approached retroperitoneoscopically.

Patient Preparation

Under general anesthesia, a 5Fr open ended ureteral catheter is inserted cystoscopically and positioned in the renal pelvis. A sterile tubing is attached to the ureteral catheter for intraoperative retrograde dilute methylene-blue injection. The patient is placed in a 45° to 60° flank position for the transperitoneal approach, and 90° lateral position for the retroperitoneal approach.
Transperitoneal Approach

Pneumoperitoneum is obtained by the Veress-needle technique. A 4 or 5 port approach is used (Figure 1). The colon is mobilized. Kidney, ureter and gonadal vein are identified and retracted laterally. Dissection proceeds cephalad along the anterior surface of the psoas muscle until the renal vein is visualized. The renal hilar vessels are carefully dissected en bloc. The kidney is mobilized within Gerota’s fascia and defatted, maintaining perirenal fat over the tumor. Intraoperative flexible laparoscopic ultrasonography is performed with a 7-MHz probe to circumferentially score an adequate margin of renal parenchyma around the tumor with a cautery J-hook. As a nephron-protective measure, 12.5g of mannitol are given intravenously 30 minutes prior to clamping. The hilar vascular pedicle is clamped en bloc with a laparoscopic Satinsky clamp taking care not to include the ureter (Figure 1). When the anticipated duration of warm ischemia time is greater than 30 minutes, we establish renal hypothermia: an Endocatch-II bag (U.S. Surgical, Norwalk, CT) is placed around the mobilized kidney, the bottom of the bag is retrieved through a 12 mm port site and 600 to 750 ml of ice-slush is delivered rapidly via 30 ml modified syringes [3]. The tumor is excised with cold Endoshears in a near-bloodless field; dissection is preferentially developed in a medial-to-lateral direction. Targeted excisional biopsies of the tumor bed may be sent for frozen section in case of suspicion regarding margin status. Collecting system is suture repaired with a running 2-0 Vicryl on CT-1 needle. Watertightness of the caliceal repair is confirmed by repeat retrograde injection of dilute methylene-blue. Renal parenchymal repair is performed with 1-0 Polyglactin on a GS-25 needle. Three to 5 interrupted sutures are placed over a pre-prepared Surgicel bolster (Johnson & Johnson, New Brunswick, NJ) that has been positioned over the cut surface of the kidney. A Hem-o-Lok clip (Weck Closure System, Research Triangle Park, NC) is secured on the suture to prevent it from pulling through. Biologic hemostatic gelatin-matrix-
thrombin tissue sealant FloSeal (Baxter Healthcare, Deerfield, IL) is applied to the cut renal parenchymal surface underneath the bolster. Another Hem-o-Lok clip is applied to the suture flush with the opposite renal surface, compressing the kidney. The suture is then tightly tied across the bolster, maintaining adequate parenchymal compression. The hilum is unclamped, and the Satinsky clamp is removed only once hemostasis is confirmed. Mannitol 12.5g and furosemide 10-20 mg is given intravenously prior to unclamping. The en bloc specimen is extracted in an EndoCatch bag. The abdomen is re-inspected after 5 to 10 minutes of zero pneumoperitoneum. A Jackson-Pratt drain is left in patients in whom pelvicaliceal repair is performed.

**Retroperitoneal Approach**

Following balloon dilation and placement of 3 ports (Figure 2), the renal artery and vein are dissected individually to facilitate application of laparoscopic bulldog clamps on the renal artery (2 clamps) and renal vein (1 clamp). Because of the limited space in the retroperitoneum, Satinsky clamp for hilar control is suboptimal. Similar to the transperitoneal approach, the tumor is excised, and renal parenchymal is repaired with caliceal suturing as necessary. The bulldog clamp is removed from the renal vein initially, followed by the artery. A Penrose drain is left when pelvicaliceal repair is performed.

**RESULTS**

**Overall Data**

Mean age was 58 years, mean tumor size was 2.9 cm, 31% of the tumors were greater than 3 cm in size, 5% patients had tumor in a solitary kidney, 40% had a central tumor, 54% had a peripheral tumor and 6% had a hilar tumor. Indication for surgery was elective in 46%, relative in 26% and absolute in 28%. The transperitoneal approach was employed in 65% of the cases. Mean warm ischemia time was 32 minutes. Renal cell carcinoma was confirmed on pathology in 75% of the tumors.
**Transperitoneal vs Retroperitoneal Approach**

When comparing 100 patients undergoing transperitoneal LPN with 63 patients undergoing retroperitoneal LPN, the transperitoneal approach was associated with a significantly longer operative time (3.5 vs 2.9 hours, \( p < 0.001 \)) and longer hospital stay (2.9 vs 2.2 days, \( p < 0.01 \)). Blood loss, perioperative complications, postoperative functional outcomes, and histological outcomes were comparable [4].

**Impact of Warm Ischemia**

We evaluated the impact of warm ischemia time on renal function in 179 patients after LPN. Mean warm ischemia time was 31 minutes (4-55 min). Function of the operated kidney, evaluated by renal scintigraphy, was reduced by a mean of 29% corresponding to the amount of parenchyma excised. No significant change in renal function when stratifying patients according to duration of warm ischemia, age and or baseline serum creatinine. Preexisting azotemia and advanced age increased the risk of postoperative kidney dysfunction especially when the duration of warm ischemia was greater than 30 minutes [5].

**Heminephrectomy**

We compared 41 patients who underwent laparoscopic heminephrectomy (defined as excision of >30% of renal parenchyma) with 41 patients who underwent less substantial LPN (less than 30% resection). The heminephrectomy group had a longer warm ischemia time (39 vs 33 minutes; \( p < 0.02 \)).

Estimated blood loss and operative time was increased (150 vs 100 mL; \( p < 0.28 \)) and (220 versus 190 minutes; \( p < 0.09 \)) but without a statistical significance. The analgesic requirements, hospital stay, overall complications, functional outcomes and surgical margins were comparable [6].

**Central vs Peripheral Tumor**

We compared patients who underwent LPN for central tumor (n= 154) to patients who underwent LPN for peripheral tumor (n= 209). The central group was associated with larger tumor (3.0 vs 2.4 cm, \( p < 0.001 \)), larger partial nephrectomy specimens (43 vs 22 g, \( p < 0.001 \)), longer warm ischemia time (33.5 vs 30 minutes, \( p < 0.001 \)), longer operative time (3.5 vs 3 hours, \( p = 0.008 \)), longer hospital stay (2.8 vs 2.4 days, \( p < 0.001 \)) and more early postoperative complications (6% vs 2%, \( p = 0.05 \)). Intraoperative and late complications were not different. Although these differences were statistically significant, we did not observe any real clinical difference in outcomes between the groups. Median
postoperative serum creatinine was similar (1.2 vs 1.1 mg/dL) and there was no difference in surgical margins (0.8% vs 0.7%, p=0.5) [7].

Hilar Tumor

Of 362 consecutive patients who underwent LPN, 25 (6.9%) had a hilar tumor with physical contact with the renal vascular pedicle. Mean tumor size was 3.7 cm (1-6.7 cm), mean warm ischemia time was 36.4 minutes (27–48 minutes) and mean blood loss was 231 cc (50-900 cc). There was no open conversion, no kidney was lost for technical reasons and all patients had negative surgical margins [8].

Solitary Kidney

Of 430 patients, 22 (5%) patients had a solitary kidney and underwent LPN. Median tumor size was 3 cm (1.4-8.3) and warm ischemia time was 29 min (14-55 min). Median preoperative and postoperative serum creatinine was 1.1 (0.8-2.1) and 1.5 mg/dL (0.8-3.3) respectively (Calculated variation: +33%). Median preoperative and postoperative glomerular filtration rate was 67.5 and 50 ml/min/1.73m², respectively (Calculated variation: -27%). This renal function variation was proportional to the median amount (23%) of parenchyma excised. Temporary hemodyalisis for 3 weeks was required in 1 patient (4.5%) following a 60% heminephrectomy for a 6.5 cm tumor [9].

Complications

In the initial 200 patients who underwent LPN, 66 (33%) patients had a complication: 36 (18%) patients had urological complications and 30 (15%) patients had non-urological complications [10]. Detailed intra-operative, post-operative and delayed complications in 200 LPN are presented in Table 1. Since we began using the biologic hemostatic agent Floseal as an adjunctive measure, our complication rates have decreased significantly (Table 2). When comparing LPN without Floseal (n=68) to LPN with Floseal (n=63), the Floseal group had decreased overall complications (37% vs. 16%; p=0.008), and tended towards a lower rate of hemorrhagic complications (12% vs. 3%; p=0.08) and lesser urine leak (6% vs 1.5%; p=0.12) [11].

<table>
<thead>
<tr>
<th>Intra-operative complications</th>
<th>11 (5.5%)</th>
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<tbody>
<tr>
<td>Bleeding</td>
<td>8 (4%)</td>
</tr>
<tr>
<td>Bowel injury</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Resected ureter</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Pleural injury</td>
<td>1 (0.5%)</td>
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<tr>
<td>Convert to open</td>
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<tr>
<th>Post-operative complications</th>
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<tbody>
<tr>
<td>Pulmonary</td>
<td>7 (3.5%)</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>5 (2.5%)</td>
</tr>
<tr>
<td>Bleeding</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>3 (1.5%)</td>
</tr>
<tr>
<td>Urine leakage</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>2 (1%)</td>
</tr>
<tr>
<td>Gluteal fasciotomy</td>
<td>1 (0.5%)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Delayed complications</th>
<th>31 (15.5%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bleeding</td>
<td>9 (4.5%)</td>
</tr>
<tr>
<td>Urine leakage</td>
<td>7 (3.5%)</td>
</tr>
<tr>
<td>Infection</td>
<td>7 (3.5%)</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Other</td>
<td>5 (2.5%)</td>
</tr>
</tbody>
</table>
Oncological Outcomes

In our initial 100 patients, each with 3 years minimum follow-up, surgical margins were positive in 2 patients. Two other patients developed a contralateral renal tumor. No local recurrence, port site recurrence or metastasis have been noted. Overall survival was 86% and cancer-specific survival was 100% [12].

Laparoscopic vs Open Partial Nephrectomy

We compared 100 patients who underwent LPN with 100 patients who underwent open partial nephrectomy, the median surgical time was (3 vs 3.9 h; \( p<0.001 \)), estimated blood loss was (125 vs 250 mL; \( p<0.001 \)) and mean warm ischemia time was (28 vs 18 min; \( p<0.001 \)). The laparoscopic group required less postoperative analgesia, shorter hospital stay and shorter convalescence. Intraoperative complications were higher in the laparoscopic group (5% vs 0%; \( p=0.02 \)), postoperative complications were similar (9% vs 14%; \( p=0.27 \)). Functional outcomes were similar in the 2 groups: Median preoperative serum creatinine (1.0 vs 1.0 mg/dL, \( p<0.52 \)) and postoperative serum creatinine (1.1 vs 1.2 mg/dL, \( p<0.65 \)). Three patients in the laparoscopic group had a positive surgical margin compared to none in the open groups (3% vs 0%, \( p<0.1 \)) [13].

DISCUSSION

LPN has emerged as an attractive minimally invasive treatment alternative for select patients with a small renal tumor. With increasing experience and confidence we are now handle larger infiltrating tumors requiring heminephrectomy, central tumors, hilar tumors or tumor in a solitary kidney. Our technique of LPN duplicates the open partial nephrectomy technique [14]. The 3D CT scan helps in planning the procedure preoperatively. Intraoperative real-time laparoscopic ultrasonography is used as a surgical navigation device during tumor resection. We prefer the transperitoneal approach to the retroperitoneal approach, since the retroperitoneal space being smaller leads to more difficult angles for suturing. The bloodless operative field with clear visibility achieved by en bloc hilar clamping with a Satinsky clamp is essential for precise tumor excision, precise pelvicalyceal suture repair and precise parenchymal closure. Individual dissection of the renal artery and renal vein is unnecessary for adequate clamping, may cause arterial vasospasm, increase the risk of vascular injury, and increase the operating time. Intraoperative fluid management and pharmaco-renal protection is necessary. Experimental evidence suggests that the kidney

### Table 2: Complications of laparoscopic partial nephrectomy: No Floseal vs With Floseal

<table>
<thead>
<tr>
<th></th>
<th>No Floseal (n=68)</th>
<th>With Floseal (n=63)</th>
<th>( p )-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage</td>
<td>11.8%</td>
<td>3.2%</td>
<td>0.08</td>
</tr>
<tr>
<td>Urine leak</td>
<td>5.9%</td>
<td>1.5%</td>
<td>0.12</td>
</tr>
<tr>
<td>Overall complications</td>
<td>36.8%</td>
<td>16%</td>
<td>0.008</td>
</tr>
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</table>
tolerates warm ischemia for up to 30 minutes, with complete functional recovery within 1 week. When warm ischemia is predicted to last considerably longer than 30 minutes, renal hypothermia is necessary. Ice slush is our technique of choice for achieving renal hypothermia [3] duplicating open partial nephrectomy surface cooling of the kidney [15-16]. Pelvicaliceal suture repair provides a watertight closure and avoids perioperative urine leak. Tumor resection is performed using “cold” endoshares. “Hot” scissors chars the tissue, and results in poor visualization of the tumor bed and an inexact line of parenchymal incision. Parenchymal hemostasis is an important part of the procedure; the most effective method remains the application of hemostatic parenchymal sutures duplicating open surgical technique. Gelatin-matrix-thrombin tissue sealant (FloSeal) is an effective adjunct in maintaining hemostasis. Its application does not require a dry field [11].

CONCLUSION

Laparoscopic partial nephrectomy is a technically challenging procedure because of its intraoperative complexity and potential complications. It should be reserved for those with adequate prior laparoscopic experience. Initially, it should be employed in selected patients with a small tumor in an anatomically favorable location. With increasing experience in over 500 cases, we are now performing laparoscopic partial nephrectomy for more advanced and challenging tumors, which hitherto were the exclusive preserve of open partial nephrectomy. Long-term (>5 years) functional and oncological outcomes are being confirmed currently.

REFERENCES


