Kidney Cancer

Robotic Versus Laparoscopic Partial Nephrectomy for Complex Tumors: Comparison of Perioperative Outcomes

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Abstract

Background: Recent studies showed that robotic partial nephrectomy (RPN) offered outcomes at least comparable to those of laparoscopic partial nephrectomy (LPN). LPN can be particularly challenging for more complex tumors.

Objective: To compare the perioperative outcomes of patients undergoing LPN or RPN for a single renal mass of moderate or high complexity.

Design, setting, and participants: A retrospective analysis was performed for 381 consecutive patients who underwent either LPN (n = 182) or RPN (n = 199) between 2005 and 2011 for a complex renal mass (RENAL score ≥7). Perioperative outcomes were compared. Predictors of postoperative renal function were assessed using multivariable linear regression analysis.

Intervention: LPN or RPN.

Outcome measurements and statistical analysis: Perioperative outcomes were compared. Predictors of postoperative renal function were assessed using multivariable linear regression analysis.

Results and limitations: There was no significant difference between the two groups with respect to patient age, gender, side, American Society of Anesthesiologists score, Charlson comorbidity index (CCI), or tumor size. Patients undergoing LPN had a slightly lower body mass index (29.2 kg/m² compared with 30.7 kg/m², p = 0.02) and preoperative estimated glomerular filtration rate (eGFR) (81.1 compared with 86.0 ml/min per 1.73 m², p = 0.02). LPN was associated with an increased rate of conversion to radical nephrectomy (RN) (11.5% compared with 1%, p < 0.001) and a higher decrease in percentage of eGFR (–16.0% compared with –12.6%, p = 0.03). There were no significant differences with respect to warm ischemia time (WIT), estimated blood loss, transfusion rate, or postoperative complications. WIT, preoperative eGFR, and CCI were found to be predictors of postoperative eGFR in multivariable analysis. No difference in perioperative outcomes was found between moderate and high RENAL score subgroups. The retrospective study design was the main limitation of this study.

Conclusions: RPN provides functional outcomes comparable to those of LPN for moderate- to high-complexity tumors, but with a significantly lower risk of conversion to RN. This situation is likely because of the technical advantages offered by the articulated robotic instruments. A prospective randomized study is needed to confirm these findings.

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1. Introduction

Partial nephrectomy (PN) currently represents the standard of care for clinical T1 renal masses, as it can provide oncologic outcomes equivalent to those of radical nephrectomy (RN) [1]. Accumulating evidence suggests that PN can reduce the morbidity and mortality resulting from renal insufficiency [2–4]. Minimally invasive approaches to PN include laparoscopic PN (LPN) and robotic PN (RPN). LPN was first described in 1993, and duplication of open PN (OPN) techniques in a laparoscopic setting was described by Gill et al. in 2002 [5,6]. LPN has gained widespread acceptance, but OPN is still frequently used, especially in challenging cases. RPN can be regarded as an evolution of LPN, as the application of the da Vinci Surgical System allows the surgeon to overcome some of the technical challenges, such as tumor excision and renorrhaphy. In a previous study, our group showed in an initial experience that RPN offered outcomes at least comparable to those of LPN [7]. Because of high-definition, three-dimensional optics and wristed instruments, RPN may provide advantages over LPN for approaching more difficult tumors [8–10].

The aim of this study was to compare the perioperative outcomes of LPN and RPN for tumors of moderate complexity (RENAL score 7–9) to high complexity (RENAL score ≥10) as determined by the RENAL nephrometry score [11].

2. Materials and methods

2.1. Study population

Prospectively collected data from an institutional review board-approved nephrectomy database were reviewed. Patients who had multifocal tumors, solitary kidneys, or radiographic evidence of locally advanced or metastatic disease were not included. A total of 381 patients who underwent LPN or RPN for a complex renal mass (RENAL score ≥7) between 2005 and 2011 were identified. Between 2005 and 2009, all PNs for complex tumors were performed laparoscopically; after 2009, all were done robotically. The RENAL nephrometry score for these tumors was determined as previously described [11]. One hundred ninety-nine patients underwent LPN and patients who underwent RPN with respect to age, gender, laterality, Charlson comorbidity index (CCI), American Society of Anesthesiologists Physical Status classification, RENAL nephrometry score, or tumor size. Patients undergoing LPN had a slightly lower body mass index (BMI) compared with patients undergoing RPN in the overall study population (29.2 kg/m² compared with 30.7 kg/m², p = 0.020). With respect to renal function, preoperative eGFR was slightly lower in patients undergoing LPN than RPN (81.1 ml/min per 1.73 m² compared with 86 ml/min per 1.73 m², p = 0.025). This difference remained significant in the moderate-complexity tumor group (79.3 ml/min per 1.73 m² compared with 85.8 ml/min per 1.73 m², p = 0.013) but not in the high-complexity tumor group.

2.2. Outcomes

Complications were classified as intraoperative or postoperative. Postoperative complications were stratified according to the Clavien-Dindo classification [13]. Any complication after surgery was recorded. Renal function was assessed by the estimated glomerular filtration rate (eGFR), which was calculated using the Modification of Diet in Renal Disease study (MDRD) equation. The eGFR was obtained immediately prior to surgery, and the last available value was used to calculate the change in renal function.

2.3. Statistical analysis

Data were presented as mean and standard deviation or frequency and percentage for continuous and categorical variables, respectively. Bivariable comparisons were performed using the independent t test or Mann-Whitney U test for continuous data and the chi-square or Fisher exact test for categorical data.

A multiple linear regression model was fitted to study potential predictors of latest eGFR and percentage of eGFR change. Predictors of major complications (Clavien classification ≥3) were studied by multiple logistic regression. Statistical analyses were performed using PASW v.18.0 (IBM Corp. Armonk, NY, USA).

Table 1 – Demographic and tumor characteristics

<table>
<thead>
<tr>
<th></th>
<th>LPN (n = 182)</th>
<th>RPN (n = 199)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate complexity, n (%)</td>
<td>128 (70.3)</td>
<td>147 (73.9)</td>
<td>0.44</td>
</tr>
<tr>
<td>Age, yr, mean (SD)</td>
<td>59.5 (13.0)</td>
<td>58.5 (11.5)</td>
<td>0.470</td>
</tr>
<tr>
<td>Male gender, n (%)</td>
<td>112 (61.5)</td>
<td>119 (59.8)</td>
<td>0.629</td>
</tr>
<tr>
<td>Laterality right, n (%)</td>
<td>86 (47.3)</td>
<td>89 (44.7)</td>
<td>0.621</td>
</tr>
<tr>
<td>BMI, mean (SD)</td>
<td>29.2 (5.3)</td>
<td>30.7 (7.2)</td>
<td>0.020*</td>
</tr>
<tr>
<td>Charlson comorbidity index, mean (SD)</td>
<td>4.2 (1.8)</td>
<td>4.1 (1.8)</td>
<td>0.485</td>
</tr>
<tr>
<td>ASA 3–4, n (%)</td>
<td>83 (45.6)</td>
<td>104 (52.3)</td>
<td>0.178</td>
</tr>
<tr>
<td>RENAL nephrometry score, mean (SD)</td>
<td>8.7 (1.2)</td>
<td>8.6 (1.2)</td>
<td>0.279</td>
</tr>
<tr>
<td>Tumor size, cm, mean (SD)</td>
<td>4.0 (1.7)</td>
<td>3.8 (1.8)</td>
<td>0.314</td>
</tr>
<tr>
<td>Final pathology</td>
<td></td>
<td></td>
<td>0.117</td>
</tr>
<tr>
<td>Clear cell carcinoma, n (%)</td>
<td>93 (51.1)</td>
<td>118 (59.3)</td>
<td></td>
</tr>
<tr>
<td>Papillary, n (%)</td>
<td>37 (20.3)</td>
<td>27 (13.6)</td>
<td></td>
</tr>
<tr>
<td>Chromophobe, n (%)</td>
<td>10 (5.5)</td>
<td>10 (5.0)</td>
<td></td>
</tr>
<tr>
<td>CCR unclassified, n (%)</td>
<td>2 (1.1)</td>
<td>6 (3.0)</td>
<td></td>
</tr>
<tr>
<td>Other cancer, n (%)</td>
<td>3 (1.6)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Benign tumors, n (%)</td>
<td>37 (20.3)</td>
<td>38 (19.1)</td>
<td></td>
</tr>
</tbody>
</table>

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; BMI = body mass index; ASA = American Society of Anesthesiologists; CCR = clear cell renal cell carcinoma; SD = standard deviation. * Statistically significant.
Operative and early postoperative outcomes are shown in Table 2. Estimated blood loss, warm ischemia time (WIT), number of intraoperative complications, transfusion rates, and length of stay were not significantly different between the two groups. Operating room time for LPN patients was significantly longer in the moderate-complexity group (246 min compared with 182.4 min, \( p < 0.001 \)) but did not reach a statistical significance in the high-complexity group (182.4 min compared with 240.3 min, \( p = 0.47 \)). Conversion to RN was significantly higher in the LPN group (11.5% compared with 1.0%, \( p < 0.001 \)) in both moderate-complexity tumors (7.8% compared with 0.7%, \( p = 0.003 \)) and high-complexity tumors (20.4% compared with 2.0%, \( p = 0.003 \)).

Conversions to RN in both approaches are summarized in Table 3. There were no cases of conversion to open RN.

Pathologic outcomes were similar between LPN and RPN, with no significant difference in positive surgical margin rates (1.1% compared with 1.0%, \( p = 0.396 \)). With a mean follow-up of 18.3 and 8.3 mo for LPN and RPN, respectively, no local recurrence was noted. One patient presented with...
Table 5 – Renal functional outcomes in (a) overall population and (b) complexity groups

(a)  

<table>
<thead>
<tr>
<th>Variable</th>
<th>LPN (n = 182)</th>
<th>RPN (n = 199)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative eGFR, ml/min per 1.73 m², mean (SD)</td>
<td>81.1 (20.9)</td>
<td>86.0 (20.4)</td>
<td>0.025*</td>
</tr>
<tr>
<td>Latest postoperative eGFR, ml/min per 1.73 m², mean (SD)</td>
<td>68.3 (22.5)</td>
<td>74.8 (20.7)</td>
<td>0.004*</td>
</tr>
<tr>
<td>GFR change value, ml/min per 1.73 m², mean (SD)</td>
<td>–12.8 (14.2)</td>
<td>–11.2 (13.9)</td>
<td>0.270</td>
</tr>
<tr>
<td>GFR change, %, mean (SD)</td>
<td>–16.0 (16.3)</td>
<td>–12.6 (14.9)</td>
<td>0.037*</td>
</tr>
<tr>
<td>Follow-up, mo, mean (SD)</td>
<td>18.3 (17.9)</td>
<td>8.3 (10.0)</td>
<td>&lt;0.001†</td>
</tr>
</tbody>
</table>

(b)  

<table>
<thead>
<tr>
<th>Complexity</th>
<th>Moderate RENAL NS (n = 275)</th>
<th>High RENAL NS (n = 106)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preoperative eGFR, ml/min per 1.73 m², mean (SD)</td>
<td>79.3 (20.3)</td>
<td>85.8 (22.0)</td>
<td>0.013†</td>
</tr>
<tr>
<td>Latest postoperative eGFR, ml/min per 1.73 m², mean (SD)</td>
<td>66.8 (20.9)</td>
<td>74.7 (22.1)</td>
<td>0.003†</td>
</tr>
<tr>
<td>GFR change value, ml/min per 1.73 m², mean (SD)</td>
<td>–12.6 (14.3)</td>
<td>–11.1 (14.0)</td>
<td>0.417</td>
</tr>
<tr>
<td>GFR change, %, mean (SD)</td>
<td>–15.7 (16.2)</td>
<td>–12.7 (14.9)</td>
<td>0.121</td>
</tr>
<tr>
<td>Follow-up, mo, mean (SD)</td>
<td>19.3 (17.9)</td>
<td>8.4 (10.4)</td>
<td>&lt;0.001†</td>
</tr>
</tbody>
</table>

LPN = laparoscopic partial nephrectomy; RPN = robotic partial nephrectomy; NS = nephrometry score; eGFR = estimated glomerular filtration rate; SD = standard deviation; GFR = glomerular filtration rate.

† Statistically significant.

4. Discussion

PN has become the method of choice for the management of a clinical stage T1 renal mass, since a number of studies have shown that there is no difference in overall or cancer-specific survival between PN and RN [14,15]. In certain situations, such as patients presenting with a renal mass in a solitary kidney or stage IV chronic kidney disease, PN can provide excellent cancer control while avoiding dialysis. Although the open approach has been the reference standard for performing PN, minimally invasive approaches have quickly gained traction. LPN has evolved to duplicate the technique of OPN, with comparable perioperative outcomes and cancer-specific survival [16–18]. However, LPN can be particularly challenging for more complex tumors, such as large, completely endophytic, or hilar masses. Moreover, functional outcomes for patients with a solitary kidney and a renal mass were better with OPN when compared with LPN [19].

In these cases, RPN may provide an advantage over LPN because of the increased number of degrees of freedom and...
improved three-dimensional visualization of the operative field. Particularly, the powered wrists of the robotic surgical system are well suited to perform the excision and renorrhaphy, which can be especially challenging for large or hilar tumors. Our group showed in a previous study that RPN and LPN had comparable outcomes [7], but tumor complexity had not been assessed in these first cases of the learning curve.

Thus, the goal of our study was to compare the abilities of RPN and LPN to approach particularly complex tumors. Then, to go further in the evaluation of the capabilities of both techniques to deal with high complexity, we separated these complex tumors into moderate- and high-complexity tumors. To assess the complexity of a renal mass, we used the RENAL nephrometry score developed by Kutikov and Uzzo [11]. Other scores, such as the Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) classification and the centrality (C) index, have been described [20,21]. According to Okhunov et al, all three scores were predictors of WIT and percentage change in postoperative creatinine [22]. Hew et al. showed that the RENAL and PADUA scores were both able to predict the risk of postoperative complications [23]. We arbitrarily chose the RENAL score, since it is frequently used in the literature. The RENAL score predicts postoperative complications similar to the PADUA score and provides comparable descriptions of renal tumors when compared with the C index.

This system identifies masses with RENAL scores between 7 and 9 as moderate complexity and masses with scores between 10 and 12 as high complexity. In our study, LPN and RPN had comparable results concerning perioperative variables and functional outcomes. In particular, WIT was not significantly different between LPN and RPN, but this observation may reflect surgeon experience in performing LPN.

Pure laparoscopy is technically demanding, and robotics has the potential to facilitate surgery, especially for surgeons with limited experience in minimally invasive techniques [24]. In this series, both techniques were performed by experienced, high-volume laparoscopic and robotically assisted surgeons. This fact probably explains why the differences reported between LPN and RPN are quite subtle and not significant.

It is interesting to note that we found that patients undergoing RPN had a significantly higher postoperative eGFR and a lower percentage change in eGFR. However, possible confounding variables that may explain this observation include a higher preoperative eGFR and a shorter median follow-up time for the RPN group. Importantly, surgical approach was not a predictor of postoperative eGFR or postoperative percentage change in eGFR in our multivariable linear regression model, confirming that LPN and RPN have similar functional outcomes.

The MDRD equation has limitations for eGFR evaluation [25]. However, preoperative and postoperative renograms were only available for a limited number of patients.

WIT is a well-known predictor of postoperative eGFR [26]. However, recent studies show that the percentage of functional volume preservation is the primary determinant of the long-term functional outcome in patients whose ischemia time is within acceptable limits [27]. Probably the larger the volume resected, the longer the WIT. However, in our study, the volume of resection was not available for our population.

CCI was found to be an independent predictor of postoperative eGFR in the multivariable analysis. This finding is not surprising and is probably related to the age and the cardiovascular comorbidities used to calculate the CCI [28].

Perhaps the most salient difference between the two approaches is that LPN is associated with a 10-fold higher rate of conversion to RN when compared with RPN. This result was observed even for two experienced laparoscopic surgeons. Given the concern of developing chronic kidney disease and the associated increased risk of cardiovascular events [4,29] after RN, RPN may be particularly well suited in the extirpation of renal masses with RENAL nephrometry score $\geq 7$ so that this late complication can be specifically avoided. Retrospectively, it is difficult to know if all the patients ultimately undergoing an LRN could not have benefited from an open conversion rather than a conversion to LRN. Among patients who lost a kidney, most had hilar involvement or insufficient residual kidney volume. However, this issue is critical, since OPN is still considered a standard of care. Indeed, according to Gill et al, RN rates are higher in LPN groups than in OPN groups [16].

Several limitations of the present study must be noted. It is a retrospective study and subject to all the biases of such a design. Additionally, most of the RPN cases were performed toward the latter half of the study period. Thus, the surgeons had a significant number of cases in which to build experience prior to starting the RPN experience. Total reconstruction time and renorrhaphy were not recorded, so we are unable to comment on intracorporeal suturing in pure laparoscopy compared with robotics. Another criticism is that the cost of RPN was not taken into account in this study. A formal cost–benefit analysis of RPN compared with LPN will need to be performed. Another limitation is that oncologic outcomes other than surgical margins are not reliable, given the limited follow-up, especially in the RPN group.

5. Conclusions

RPN provides perioperative outcomes comparable to those of LPN for the excision of renal masses of moderate to high complexity. Additionally, RPN is associated with a significantly lower conversion rate to RN when compared with LPN. This situation is likely because of the technical advantages offered by the articulated robotic instruments. A prospective randomized study is needed to confirm these findings.

Author contributions: Georges-Pascal Haber had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Long, Haber.
Acquisition of data: Long, Guillotreau, Eyraud, Laydner.
Analysis and interpretation of data: Yakoubi, Long, Haber.
Drafting of the manuscript: Lee, Long, Haber.
Critical revision of the manuscript for important intellectual content: Kaouk, Stein, Autorino, Haber.

Statistical analysis: Yakoubi, Long.

Obtaining funding: Long, Haber.

Administrative, technical, or material support: Haber, Kaouk, Stein.

Supervision: Haber.

Other (specify): None.

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References


