Factors Influencing the Feasibility of Segmental Artery Clamping During Retroperitoneal Laparoscopic Partial Nephrectomy

Jian Qian, Jie Jiang, Pu Li, Shaobo Zhang, Meiling Bao, Chao Qin, Xiaoxin Meng, Pengfei Shao, and Zengjun Wang

OBJECTIVE
To investigate factors that may predict successful precise segmental artery clamping during retroperitoneal laparoscopic partial nephrectomy (LPN) for treatment of T1 kidney tumor.

PATIENTS AND METHODS
Patients with clinical T1 tumors (n = 248) who received retroperitoneal LPN from June 2012 through February 2018 were reviewed, including demographics and clinical features. However, only 225 cases (90.7%) were available to analyze. Precise segmental artery clamping was the first clamping method selected during the LPN. If unsuccessful, conversion to main renal artery clamping was conducted. The perioperative features and functional outcomes of the 2 clamping types were compared.

RESULTS
Of the 225 patients, 190 procedures were effectively performed using segmental artery clamping, while 35 (15.6%) were converted to main renal artery clamping. None were converted to open surgery. Clamping the main renal artery was associated with longer operative time, less estimated blood loss, and higher glomerular filtration rate reduction, compared with successful segmental artery clamping. Univariable analyses determined that the following features affected the feasibility of segmental artery clamping: gender; hypertension; tumor location, growth pattern, and targeted artery number; R.E.N.A.L. nephrometry score (RNS); and Mayo adhesive probability (MAP) score. The multivariable analyses indicated that male gender, high RNS, and elevated MAP score were independent factors lowering the viability of segmental artery clamping.

CONCLUSION
LPN with segmental artery clamping is generally safe for removing T1 kidney tumors. Extra cognizance may be required in men and cases with high RNS or MAP score.

Partial nephrectomy has recently been recommended as a standard surgical treatment for T1a and selective T1b kidney tumors. Precise segmental artery clamping is a well-adopted technique used in laparoscopic partial nephrectomy. A series of techniques and procedures have been introduced to standardize and simplify the operation. However, because of the complexity of the renal hilar anatomy, experienced surgical skills are still required.

Our previous work focused on the technical safety, feasibility, and oncological outcomes of laparoscopic partial nephrectomy with segmental artery clamping, and it was noticed that not all patients were suitable for successful segmental artery clamping. In the event of unsuccessful segmental artery clamping, conversion to main renal artery clamping is the main option, but is thought to have unfavorable perioperative outcomes. An attempt and failure to clamp the segmental artery may increase the operative or warm ischemic time, affecting renal function after surgery. Accurately predicting the viability of segmental artery clamping could avoid an unnecessary attempt and thus shorten operative and clamping time. However, there is no effective means to predict the surgical difficulty when performing partial nephrectomy with segmental artery clamping.

Several studies have reported factors that influence the success of partial nephrectomy, but few have focused on segmental artery clamping. According to our experience, endophytic tumors or adherent perinephric fat may increase the surgical difficulty, making perioperative conversion to main artery clamping more likely. The
R.E.N.A.L. nephrometry score (RNS) is an effective method to fully evaluate the characteristics of the renal mass and can aid the surgical difficulty. In addition, the Mayo adhesive probability (MAP) score, introduced by Davidiuk et al. in 2014, can accurately predict the presence of adherent perinephric fat in patients.

The present study retrospectively analyzed a multitude of factors that may potentially affect the surgical feasibility of performing segmental artery clamping during laparoscopic partial nephrectomy.

PATIENTS AND METHODS

Patients

A retrospective review was conducted of 248 patients who underwent laparoscopic partial nephrectomy, with planned precise segmental artery clamping, from June 2012 through February 2018. All the patients had received a diagnosis of cT1 renal tumor (≤7 cm in diameter) and had normal contralateral renal function. Patients with atrophic or solitary kidney were excluded in this study. But data from only 225 cases (90.7%) was available to analyze.

The split renal function of 85.3% of the patients was evaluated prior to surgery and 3 months after surgery using renal scintigraphy with a camera-based Gate’s method, measuring the renal uptake of technetium Tc-99m diethylenetriamine pentaacetic acid. Specifically, in this way the split renal function was evaluated in 85.8% and 82.9% of patients treated with segmental artery clamping and main renal artery clamping, respectively.

Surgical Procedures

All the laparoscopic partial nephrectomies were performed by the same laparoscopic surgeon (P.S.) through a retroperitoneal approach. Precise segmental renal artery clamping was initially tried, under the guidance of dual-source computed tomography (CT) as described in our previous work. Briefly, all the patients underwent CT and dual-source CT before surgery to establish 3D dynamic renal vascular models (Fig. 1).

Patients were administered general anesthesia and placed in the lateral decubitus position. Four ports in the lumbar region were applied. The targeted segmental renal arteries were isolated at the pulsatile position, as well as the main renal artery in case of unfortuitous events. The targeted segmental renal arteries were clamped with bulldogs before removing the tumor. The parenchyma was incised and the tumor was excised closely around its capsule. Transected vessels in the tumor bed and incised calices were sutured and repaired. The parenchymal defect was closed using absorbable sutures or Hem-o-lok clips to tighten and secure the sutures at each exit. Finally, the bulldogs were unclamped after completion of renorrhaphy.

Conversion to main artery clamping was conducted when targeted arteries were difficult to dissect, kidney and tumor were hard to isolate from perinephric tissues, there was much bleeding or insufficient occlusion, or hilar anatomy was difficult to recognize and separate (Supplementary Table S1).

Clinical Data

The patients’ demographics, body mass index, and histories of hypertension, diabetes, and smoking were collected. The clinicopathologic characteristics of the tumor were noted, including:

**Figure 1.** 3-dimensional dynamic renal vascular models and intraoperative vessels. (A-D), 3-D renal vascular models rebuilt according to CTA images. Artery, vein, and pelvis were showed in the models. Targeted artery including numbers and position were indicated. (E) Hilar anatomy was magnified to guide the surgical procedures more clearly and precisely. (F) Intraoperative vascular anatomy was highly consistent with preoperative models. (Color version available online.)
size; location (polar, anterior, posterior, and striding); growth pattern (exophytic, mesophytic, and endophytic); number of targeted renal arteries feeding the tumor; and RNS. In addition, the following features were carefully collected: MAP score; perioperative data such as operative and clamping time, estimated blood loss, pathology, and positive surgical margin; postoperative glomerular filtration rate (GFR); and complications.

A striding tumor was defined as a lesion located on both the anterior and posterior sides of the kidney. Exophytic, mesophytic, and endophytic tumors were considered to extend >60%, 40%-60%, and <40%, respectively, from the natural surface of the kidney.18

The RNS and MAP score were masked by 2 separate radiologists according to Kutikov’s and Uzzo’s16 and Davidiuk et al.’s15 work, respectively. Complications were graded based on Clavien’s classification.19

Statistical Analysis
All the data were analyzed by STATA 14.0 software. Segmental artery clamping and main artery clamping were compared using the t test or chi-squared test. Univariable and multivariable logistic regression analyses were utilized to investigate associations between patient/tumor characteristics and conversion to main artery clamping. P < .05 was considered statistically significant.

RESULTS

Patient and Tumor Characteristics
The 225 patients consisted of 152 men (67.6%) and 73 women (32.4%), and 31.6% of the patients had a history of smoking (Table 1). Hypertension and diabetes was diagnosed in 27.1% and 14.2% of the patients, respectively. Regarding the tumor characteristics, the mean tumor diameter was 3.52 ± 1.48 cm, with 70.7% and 29.3% in T1a and T1b stage. The median RNS was 6 (range 4-11). The median MAP score was 2 (range 0-5). The majority of the tumors (75.1%) were clear cell carcinoma, with angiomyolipoma (11.6%), papillary carcinoma (7.6%), oncocytoma (3.6%), and chromophobe cell carcinoma (2.22%) making up the balance.

Perioperative Outcomes
Of the 225 patients, the segmental renal arteries were successfully isolated and clamped in 190 cases (84.4%) during surgery (Table 2). The balance of 35 (15.6%) patients required conversion to main renal artery clamping. No patients received radical nephrectomy or open surgery. When performing segmental artery clamping, the mean operative time was 87 minutes and the mean clamping time was 27 minutes. When performing main artery clamping the mean operative time was 92 minutes and the mean clamping time was 29 minutes. The estimated blood loss was 215 ± 120 mL and 170 ± 100 mL, respectively.

Table 1. Patient and tumor characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Overall (n = 225)</th>
<th>Segmental Artery Clamping (n = 190)</th>
<th>Main Artery Clamping (n = 35)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>54.8 ± 12.7</td>
<td>54.3 ± 12.9</td>
<td>57.3 ± 11.4</td>
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<td>Body mass index</td>
<td>23.0 ± 1.74</td>
<td>22.9 ± 1.63</td>
<td>23.4 ± 1.86</td>
<td>0.138</td>
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<tr>
<td>Gender, n (%) Male</td>
<td>152 (67.6)</td>
<td>120 (63.2)</td>
<td>32 (91.4)</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>73 (32.4)</td>
<td>70 (36.8)</td>
<td>3 (8.6) -</td>
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<tr>
<td>Hypertension, n (%) Yes</td>
<td>61 (27.1)</td>
<td>46 (24.2)</td>
<td>15 (42.9)</td>
<td>0.026</td>
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<tr>
<td></td>
<td>No</td>
<td>164 (72.9)</td>
<td>144 (75.8)</td>
<td>20 (57.1) -</td>
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<tr>
<td>Diabetes, n (%) Yes</td>
<td>32 (14.2)</td>
<td>25 (13.2)</td>
<td>7 (20.0)</td>
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<tr>
<td></td>
<td>No</td>
<td>193 (85.8)</td>
<td>165 (86.8)</td>
<td>28 (80.0) -</td>
</tr>
<tr>
<td>Smoking, n (%) Yes</td>
<td>71 (31.6)</td>
<td>58 (30.5)</td>
<td>13 (37.1)</td>
<td>0.553</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>154 (68.4)</td>
<td>132 (69.5)</td>
<td>22 (62.9) -</td>
</tr>
<tr>
<td>Preoperative GFR, mL/ min*</td>
<td>45.2 ± 8.5</td>
<td>45.4 ± 8.95</td>
<td>44.2 ± 5.52</td>
<td>0.474</td>
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<tr>
<td>Tumor size, cm</td>
<td>3.52 ± 1.48</td>
<td>3.45 ± 1.41</td>
<td>3.90 ± 1.76</td>
<td>0.098</td>
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<tr>
<td>RNS, median (range)</td>
<td>6 (4-11)</td>
<td>6 (4-10)</td>
<td>9 (4-11)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MAP, median (range)</td>
<td>2 (0.5)</td>
<td>2 (0.5)</td>
<td>4 (1.5)</td>
<td>&lt;0.001</td>
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<tr>
<td>T stage, n (%) T1a</td>
<td>159 (70.7)</td>
<td>138 (72.6)</td>
<td>21 (60.0)</td>
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<tr>
<td></td>
<td>T1b</td>
<td>66 (29.3)</td>
<td>52 (27.4)</td>
<td>14 (40.0) -</td>
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<td>Clamped arteries, n (%)</td>
<td>116 (51.6)</td>
<td>108 (56.8)</td>
<td>8 (22.9)</td>
<td>&lt;0.001</td>
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<tr>
<td></td>
<td>2</td>
<td>86 (38.2)</td>
<td>68 (35.8)</td>
<td>18 (51.4) -</td>
</tr>
<tr>
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<td>3</td>
<td>23 (10.2)</td>
<td>14 (7.4)</td>
<td>9 (25.7) -</td>
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<tr>
<td>Tumor location, n (%)</td>
<td>Polar</td>
<td>69 (30.7)</td>
<td>63 (33.2)</td>
<td>6 (17.1) 0.001</td>
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<td></td>
<td>Anterior</td>
<td>57 (25.3)</td>
<td>52 (27.4)</td>
<td>5 (13.4) -</td>
</tr>
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<td></td>
<td>Posterior</td>
<td>51 (22.7)</td>
<td>43 (22.6)</td>
<td>8 (22.9) -</td>
</tr>
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<td></td>
<td>Striding</td>
<td>48 (22.3)</td>
<td>32 (16.8)</td>
<td>16 (45.7) -</td>
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<tr>
<td>Growth pattern, n (%)</td>
<td>Exophytic</td>
<td>110 (48.9)</td>
<td>102 (53.7)</td>
<td>8 (22.9) &lt;0.001</td>
</tr>
<tr>
<td></td>
<td>Mesophytic</td>
<td>75 (33.3)</td>
<td>62 (32.6)</td>
<td>13 (37.1) -</td>
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<tr>
<td></td>
<td>Endophytic</td>
<td>40 (17.8)</td>
<td>26 (13.7)</td>
<td>14 (40.0) -</td>
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<tr>
<td>Pathology, n (%)</td>
<td>Clear cell carcinoma</td>
<td>169 (75.1)</td>
<td>140 (73.7)</td>
<td>29 (82.8) 0.305</td>
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<td>Angiomyolipoma</td>
<td>26 (11.6)</td>
<td>25 (13.2)</td>
<td>1 (2.9) -</td>
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<td></td>
<td>Papillary carcinoma</td>
<td>17 (7.6)</td>
<td>13 (6.8)</td>
<td>4 (11.4) -</td>
</tr>
<tr>
<td></td>
<td>Oncocytoma</td>
<td>8 (3.6)</td>
<td>7 (3.7)</td>
<td>1 (2.9) -</td>
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<tr>
<td></td>
<td>Chromophobe cell carcinoma</td>
<td>5 (2.2)</td>
<td>5 (2.6)</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

* Affected side.
when segmental artery clamping was successful or not successful. In most cases, a satisfactory ischemic area was achieved by clamping 1 (51.6%), 2 (38.2%), or 3 (10.2%) branches, consistent with dual-source CT before surgery.

The total complication rate was 16.9% (Table 2). Sixteen patients were found with hematuria (grade 1) postoperatively, with no intervention taken. Fifteen patients required blood transfusion due to major hemorrhage (grade 2). Seven patients received branch embolization 1 or 2 days after surgery, because of postoperative hemorrhage (grade 3a).

### Influences on Perioperative and Functional Outcomes in Patients With Segmental Artery Clamping or Conversion to Main Artery Clamping

Operative time, clamping time, estimated blood loss, GFR reduction, and complication rates were compared between successful segmental artery clamping and conversion to main artery clamping (Table 2). Conversion to main renal artery clamping was associated with significantly longer operative time ($P = .017$), less estimated blood loss ($P = .041$), and lower GFR ($P = .035$). However, the 2 methods were comparable with regard to clamping time ($P = .094$) and complication rate ($P = .143$).

### Associations Between Patient/Tumor Features and Successful Segmental Artery Clamping

Univariable and multivariable logistic regression analyses were performed for the patient and tumor characteristics that may influence the successful performance of segmental artery clamping (Table 3). In the univariable analyses, the independent factors affecting the feasibility to perform segmental artery clamping were: gender ($P = .003$); hypertension ($P = .025$); tumor location ($P = .003$), growth pattern ($P = .034$), and targeted artery number ($P < .001$); RNS ($P < .001$); and MAP score ($P < .001$). The multivariable analyses showed that only gender ($P = .024$), RNS ($P = .001$), and MAP score ($P < .001$) were independent factors that may influence the successful performance of segmental artery clamping.

### DISCUSSION

Precise segmental artery clamping during partial nephrectomy has proved safe and feasible for removing clinical T1 kidney tumors, with favorable postoperative renal function. However, complicated hilar anatomy and precise artery isolation are still big challenges for junior surgeons. Unsuccessful segmental artery clamping and conversion to main artery clamping may affect the perioperative and functional outcomes. In the present study, for cases converted to main artery clamping, the operative time was longer, and estimated blood loss and postoperative GFR was significantly less. Male gender, higher RNS, and increased MAP score were confirmed independent factors that decreased the success rate of segmental artery clamping in the multivariable analyses.
The longer operative time may be associated with adherent perinephric fat and the process of conversion. Adherent perinephric fat added to the difficulty of tumor isolation, which led to a longer surgery. The reduced estimated blood loss in patients who received main artery clamping patients may be attributed to the complete cessation of blood flow to the kidney. However, the estimated blood loss for both clamping types was relatively low and may not be of significance. There was no evidence of associations between postoperative GFR and operative time or estimated blood loss, and the clamping times of the 2 techniques were similar. Because prolonged warm ischemic time may influence renal function after surgery, we noted that the time to perform main artery clamping was relatively longer compared with segmental artery clamping. However, its potential influence on renal function remains unclear. The rate of complications was also statistically similar between the groups, although higher in patients for whom segmental artery clamping failed. Due to a low complication rate in both groups, a larger sample size is needed to reveal the actual risk of surgical conversion.

Because of the increased operative time and worsened postoperative GFR associated with unsuccessful segmental artery clamping, it is necessary to find factors that may predict this surgical difficulty. Although there were studies of predictors of surgical difficulty for partial nephrectomy, few are specific to segmental artery clamping. In the present study, we analyzed tumor- and patient-specific characteristics that may influence the feasibility of segmental artery clamping. The univariable analyses showed that gender, hypertension, tumor location, growth pattern, and targeted artery number, RNS and MAP score were associated with the conversion to main artery clamping. The multivariable analyses indicated that only male gender, higher RNS, and higher MAP score were independent factors that lowered the feasibility of segmental artery clamping.

We first considered that the difficulty of surgery was related to tumor-specific characteristics, but how such features affect the feasibility of segmental artery clamping is unknown. The present results of the univariable analyses showed that tumor location, growth pattern, targeted artery number, RNS, and MAP score were associated with segmental artery clamping feasibility. Although the tumor location and growth pattern may affect the clamping type, the multivariable analyses indicated no association with successful segmental artery clamping. The RNS reflects information about tumor location and growth pattern in a detailed score which makes it convenient to analyze. RNS is a well-accepted scoring system that is based on tumor-specific factors, and was an independent risk factor of conversion to main artery clamping (P < .001). Moreover, each R.E.N.A.L. factor was individually analyzed for affecting the clamping type. The results showed that the E score (exophytic/endophytic properties) was associated with conversion (P = .013, data not shown). This suggests that an endophytic tumor may be more difficult than the exophytic for performing segmental artery clamping.

On the other hand, the RNS does not consider perinephric factors that may complicate the technical aspects of partial nephrectomy. When performing the partial nephrectomy, we found that both tumor-specific and patient-specific factors contributed to the difficulty of surgery, and possibly the difficulty of segmental artery clamping. Bylund et al were the first to report that male gender, stranding around the kidney, and greater thickness of perinephric fat may be associated with adherent perinephric fat encountered intraoperatively during the partial nephrectomy. Male gender was confirmed as an independent risk factor affecting the possibility of main artery clamping in the present study (P = .008), and men have been reported more likely to have greater perirenal fat and stranding, which is consistent with our experience. Stranding and perirenal fat are the main evaluative indicators of the MAP score, which was introduced to assess perinephric fat adhesion with high sensitivity and specificity by Davidiuk et al. In the present study, we also found a strong association between MAP score and conversion to main artery clamping (P < .001).

The present study determined that male gender, higher RNS, and elevated MAP score were independent factors predicting possible perioperative conversion from segmental artery clamping to main artery clamping, and consequently unfavorable perioperative and functional outcomes. Extra cognizance may be required in men and cases with high RNS or MAP score when performing segmental artery clamping.

The results of this study are limited, in that it is a retrospective analysis from a single center and is mainly focused on laparoscopic surgery. An investigation that includes more features and a more detailed scoring system is needed to evaluate the feasibility of segmental artery clamping during laparoscopic partial nephrectomy. Robotic system and novel techniques, such as Tilepro and ICG, used in robotic assisted surgery should be taken into account for the advantages in aiding more precise artery dissection. Moreover, a comparison between robotic assisted and laparoscopic partial nephrectomy for both segmental artery clamping and main artery clamping should be made.

In conclusion, laparoscopic partial nephrectomy segmental artery clamping is a safe and reliable approach to remove T1 kidney tumors. Male gender, higher RNS, and higher MAP score may lower the success rate of segmental artery clamping.

Acknowledgment. The study was approved by the Local Ethics Committees of the First Affiliated Hospital with Nanjing Medical University, Nanjing, China. Written informed consent was obtained from all participants involved in this study. The authors thank Dr. Jin Xu for his help in data analysis.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.urology.2019.03.024.
References