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Comparison of Selective Parenchymal Clamping to Hilar Clamping During Robotic-assisted Laparoscopic Partial Nephrectomy

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Abstract

OBJECTIVE—To compare perioperative outcomes after robotic-assisted laparoscopic partial nephrectomy (RALPN) with hilar clamping vs parenchymal clamping.

METHODS—A retrospective, single-institution review of the patients undergoing RALPN with hilar or parenchymal clamping was performed. Associations between perioperative factors and clinicopathologic outcomes were determined using the *t* test, Fisher's exact test, and multivariate linear regression.

RESULTS—In 51 patients undergoing RALPN, 36 (71%) and 15 (29%) were performed with hilar and parenchymal clamping, respectively. Median tumor diameter was 2.8 cm for both groups (range, 1.1–6.1; $P=.93$). Tumor complexity by nephrometry score was mild (69% vs 80%), moderate (29% vs 20%), and high (2% vs 0%) in the respective groups ($P=.65$). Operative time was significantly shorter in the parenchymal clamp group (median 245 vs 320 minutes; $P<.0001$). There was no difference in blood loss and need for transfusion. On multivariate analysis, hilar clamping ($P<.01$), higher body mass index ($P=.01$), and higher complexity tumors ($P=.02$) were significantly associated with longer operative times. The parenchymal clamp group had better preservation of immediate postoperative glomerular filtration rate (GFR) from baseline to postoperative day 2 (median GFR 0 vs -18 mL/min/1.73 m², $P=.02$). These differences from baseline did not persist (median GFR -6 vs -7 mL/min/1.73 m², $P=.35$) at a median follow-up of 6.6 months. Final pathology determination of malignancy ($P=.51$) and positive margin rates ($P=.26$) were similar in both groups.

CONCLUSION—Compared with hilar clamping, selective regional ischemia with the parenchymal clamp for mild-moderately complex tumors is feasible and safe during RALPN. Parenchymal clamping is associated with enhanced immediate preservation of GFR and shorter operative times.

Partial nephrectomy (PN) is the standard of care for technically amenable small renal masses,¹ with improved overall survival compared with radical nephrectomy.^{2,3} Despite an increase in the use of nephron-sparing approaches for renal preservation over time,⁴ there are wide variations in the use of PN and it remains underused.^{5,6} In 2006, the usage rates of

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PN for patients with small renal masses <4 cm was 45% in the United States overall compared with over 70%–80% at tertiary care centers in the United States and Europe.^{4,7,8}

There is evidence that the introduction of robotic technology has been associated with an increased use of PN.^{9,10} Compared with laparoscopic partial nephrectomy, robotic-assisted laparoscopic partial nephrectomy (RALPN) has equivalent morbidity and oncologic outcomes and might provide decreased warm ischemia time, blood loss, and hospital stay.¹¹ This might be explained by the technical advantages of this approach for tumor dissection and intracorporeal suturing over laparoscopic partial nephrectomy, which is considered challenging with a steep learning curve.^{12,13} Techniques that might further reduce the complexity of RALPN might allow more inexperienced surgeons to perform PN. It is often necessary to interrupt blood flow during PN for mass excision and defect reconstruction. At the same time, minimizing renal ischemia time during PN is necessary to prevent deterioration of renal function in the short and long term.¹⁴

A method for vascular control for polar lesions is selective regional ischemia with a laparoscopic parenchymal clamp (Aesculap AG, Tuttlingen, Germany) first introduced by Simon et al.¹⁵ This laparoscopic instrument has an adjustable locking ratchet handle and an open curved jaw that fits through a 10-mm trocar port (Fig. 1A). The clamp can be placed around the kidney to isolate peripherally located masses and create regional ischemia. Single^{15,16} and multi-institutional¹⁷ series have reported feasibility of the parenchymal clamp in select patients undergoing RALPN. Proposed advantages of the parenchymal clamp include sparing most kidneys from ischemia, allowing longer time for excision and reconstruction, and requiring less hilar dissection. However, there have been no comparison studies with the parenchymal clamp. The purpose of this study was to compare perioperative outcomes after RALPN with hilar clamping vs parenchymal clamping.

MATERIALS AND METHODS

With institutional review board approval, consecutive patients undergoing RALPN with hilar clamping or parenchymal clamping from December, 2009, to February, 2013, at our institution were identified. RALPN cases that were performed with segmental artery clamping or without clamping (“off-clamp”) were excluded. Patients with solitary kidneys, multifocal tumors, or evidence of locally advanced or metastatic disease were excluded. Patient characteristics and perioperative data were entered into a retrospective database. Estimated glomerular filtration rate (GFR) was calculated using the Modification of Diet in Renal Disease formula.¹⁸ The nephrometry score¹⁹ for tumors was determined from preoperative imaging and stratified into low (4–6), moderate (7–9), and high (10–12) complexity tumors. Perioperative complications within 90 days were determined from the medical record and graded using the Clavien-Dindo classification.²⁰ Last imaging follow-up is reported as interval from surgery date to most recent abdominal imaging, excluding patients with benign pathology.

Each case was evaluated to assess candidacy for parenchymal clamping. If the parenchymal clamp was initially secured but converted to hilar clamping, cases were considered in the hilar clamping group. In general, a 4-arm robotic approach with lateral camera placement

was used with 2 assistant ports in the midline or offset laterally in very obese patients (Fig. 1B). Patients were placed in a near flank position with only slight table flexion without the kidney rest. The final decision regarding pole clamp placement was made after defatting the kidney and exposing the tumor and after intraoperative ultrasound to delineate tumor margins. The pole clamp was placed through the inferior assistant port in all except 2 cases, when the fourth arm port position was used for a lateral interpolar tumor location. Various degrees of renal mobilization took place depending on the tumor location. Complete hilar dissection was performed earlier in the series; however, after experience was gained using the pole clamp, it was felt that less hilar dissection could be performed if the tumor was in the most optimal location (ie, lower pole, exophytic). Mannitol was given before clamp placement in all cases. Renal masses were excised using cold excision with scissors. Reconstruction of the base of the defect, including collecting system, was performed with various layers of 3–0 and 4–0 braided suture, followed by closure of the capsule with 2–0 braided suture using the sliding-clip renor-rhaphy technique as previously described.²¹

Statistical analyses to compare the baseline characteristics and perioperative variables of the 2 groups were performed using Student independent *t* test for continuous data and Fisher's exact test for categorical data. Multivariate linear regression was used to evaluate the association between operative time and hemostatic technique with adjustment for age, laterality (right, left, and bilateral), nephrometry score (categorical), body mass index ([BMI], continuous), previous abdominal surgery (yes/no), and American Society of Anesthesiologists classification (categorical). Statistical analyses were performed using Stata 12.1 (StataCorp LP, College Station, TX). All tests were 2-tailed, and $P < .05$ was considered statistically significant.

RESULTS

During the study period, 51 patients met inclusion criteria, of which 36 (71%) were performed with hilar clamping, and 15 (29%) were performed with selective parenchymal clamping. Table 1 shows the preoperative patient and tumor characteristics of both the groups. There were no statistically significant differences in age, sex, BMI, American Society of Anesthesiologists classification, laterality, mass location, radiologic and pathologic mass size, and nephrometry scores. Renal masses in the parenchymal clamping group were less likely located in the upper pole and more likely located in the lower pole ($P = .09$). A trend was observed toward a higher proportion of high and moderately complex nephrometry scores in the hilar clamping group.

Table 2 shows perioperative and oncologic outcomes by group. Operative time and clamp occlusion time were significantly less in the parenchymal clamp group. There was no difference in blood loss, need for transfusion, and length of stay. There were no open conversions in either group. In one patient in whom the parenchymal clamp was placed for a 2.5-cm primarily endophytic, interpolar tumor, the case was converted to hilar clamping owing to poor visualization from bleeding.

Immediate recovery of renal function was better in the parenchymal clamp group, as measured by change from baseline to postoperative day 1 (POD1; median Cr +0.1 vs +0.2

mg/dL, $P=.01$; median GFR -3 vs -18 mL/min/1.73 m², $P<.05$) and from baseline to POD2 (median Cr 0.0 vs $+0.2$ mg/dL, $P=.01$; median GFR 0 vs -18 mL/min/1.73 m², $P=.02$). However, at a combined median follow-up of 6.6 months (range, 0.1–40.9), these differences from baseline did not remain statistically significant (median Cr 0.0 vs $+0.1$ mg/dL, $P=.18$; median GFR -7 vs -6 mL/min/1.73 m², $P=.35$). Among patients with baseline GFR <60 mL/min/1.73 m² ($n = 3$ in each group), there were no differences in renal function between parenchymal and hilar clamping, respectively, from baseline to POD1 (mean Cr $+0.1$ vs $+0.2$ mg/dL, $P=.77$; mean GFR -3 vs -4 mL/min/1.73 m², $P=.94$), baseline to POD2 (mean Cr -0.1 vs $+0.3$ mg/dL, $P=.38$; mean GFR 8 vs -7 mL/min/1.73 m², $P=.42$), baseline to last follow-up (mean Cr 0.0 vs $+0.1$ mg/dL, $P=.14$; mean GFR -9 vs -6 mL/min/1.73 m², $P=.68$).

There were no positive surgical margins in the parenchymal clamp group, compared with 3 (8%) positive surgical margins in the hilar clamp group ($P=.26$). There were no tumor recurrences over the combined median imaging follow-up of 6.5 months.

In the multivariate model, parenchymal clamp use was significantly associated with shorter operative times ($P=.01$, 95% confidence interval -90 to -13 minutes). BMI ($P=.01$) and higher complexity tumors ($P=.02$) also had significant association with longer operative times.

With an overall complication rate of 25.4%, there was a similar complication rate between the parenchymal clamp group and hilar clamp group (27% vs 25%), including 2 and 1 grade III complications, respectively (Table 3). The transfusion rate was similar with 1 patient in each group ($P=.60$), and there were no urine leaks in either group.

COMMENT

Several findings from this study are important. First, parenchymal clamping is feasible and safe in patients undergoing RALPN, even for tumors of moderate complexity. Second, RALPN with parenchymal clamping is associated with significantly shorter operative and warm ischemia times compared with RALPN with hilar clamping. In this study, the median operative time in the parenchymal clamping group was 75 minutes less than in the hilar clamping group. This association remained significant when also adjusted for multiple factors, including BMI and tumor complexity. This difference might be explained by the need for less complete hilar dissection in the parenchymal clamping group. Finally, the use of the parenchymal clamp is associated with improved renal function preservation in the immediate postoperative period. At the last follow-up, the difference did not persist, and it is unknown if a difference would be observed with a larger sample size and longer follow-up.

To our knowledge, this is the first study to compare outcomes after RALPN using the parenchymal clamp compared with hilar clamping. Previous case series of parenchymal clamping have reported favorable outcomes in select tumors. In the first report on the use of the selective parenchymal clamp in RALPN, Simon et al¹⁵ reported the outcomes of 3 patients with exophytic tumors measuring 2.4–3.2 cm located in the upper (1) and lower pole (2). Operative time ranged from 203 to 275 minutes, with selective clamp time of 23–

38 minutes. There was no change in postoperative renal function, and all margins were free of tumor. According to the authors, advantages of the technique included regional ischemia sparing the remainder of the kidney, avoiding wide dissection of renal pedicle and clamping of major vessels, and the ability to rotate the kidney with the clamp. A subsequent study by Viprakasit et al¹⁶ on 3 patients reported similar safety and effectiveness. Mean clamp time ranged from 20 to 52 minutes, and all margins were negative for malignancy. Immediate postoperative renal function was similar to baseline. A multi-institutional study by Viprakasit et al¹⁷ reported outcomes after RALPN from 4 centers using the parenchymal clamp. Overall, 20 of 88 (23%) patients undergoing RALPN were treated with the parenchymal clamp with successful placement in 17 (85%). In this study, median tumor size was 2.2 (range, 1.1–7.2 cm), with median nephrometry score of 6 (range, 4–10), and 47% of patients required collecting system repair. In 3 cases, incomplete compression resulted in bleeding, decreased visualization, and conversion to hilar clamping. Median operative time was 190 minutes, and clamp time was 26 minutes. There was no change in preoperative, immediate, or last estimated GFR with a mean follow-up of 6.1 months.

Regardless of technique, the goal of clamping is to achieve a hemostatic operative field to facilitate precise tumor excision. Studies have reported that parenchymal volume preservation rather than ischemia time is the most important determinant of long-term kidney function.^{22,23} As reported by others, use of the parenchymal clamp is best suited for exophytic and peripheral tumors to allow adequate compression of the parenchyma and avoid overlap with the hilum.^{15–17} In our experience, the upper pole location might limit the placement of the clamp because of potential collisions with the robotic arms. Although the ideal tumor location is believed to be the lower pole, with aggressive mobilization of the kidney from the surrounding fat, the clamp might be used to help rotate the kidney to allow usage for lateral and posterior tumors as well. The clamp could be useful during RALPN using a retroperitoneal approach, although space is a theoretical limitation. Lateral interpolar regions might be approached with placement of the clamp along the longitudinal axis of the kidney, although in our experience, this results in more parenchyma within the clamp, less efficient occlusion of the jaws, and more oozing after excision. In some cases, after tumor excision, the clamp jaws are near the edge of the defect and in the way of suture placement to close the parenchyma. In this scenario, the base stitches are placed to oversee the collecting system and individual vessels as necessary with the clamp in place. At this point, a decision is made to remove the clamp and perform the capsular closure off-clamp or place a varying number of parenchymal stitches below the clamp. Alternatively, the clamp can be readjusted. As other investigators have noted, central and hilar tumors would not be feasible with this technique, but tumor size is not a limitation if the tumor is in an ideally located position.^{15–17}

Our findings must be interpreted within the context of limitations of our study design. Although this is the largest single institution report of use of the parenchymal clamp, the results of this retrospective study need to be confirmed in other institutions, including nontertiary care centers. Because each case was assessed for candidacy for parenchymal clamping, there is likely selection bias in the assignment of both groups. More peripheral, polar tumors might be in the parenchymal clamping group, although tumor complexity as measured by nephrometry scores was similar in both groups. In addition, longer follow-up is

needed to determine long-term oncologic and renal functional outcomes after RALPN with the parenchymal clamp. Despite these limitations, immediate and shortterm outcomes are comparable with a similar cohort undergoing hilar clamping. It is anticipated that there will be continued advancements in the instrument design of the parenchymal clamp and RALPN technique.

CONCLUSION

During RALPN, the use of the parenchymal clamp for mild-moderately complex renal tumors is feasible and safe compared with standard hilar clamping. RALPN with parenchymal clamping is associated with shorter operative times compared with RALPN with hilar clamping. Although there is better renal function in the immediate postoperative period after selective regional ischemia, these differences did not remain significant with longer follow-up. This instrument could allow for further dissemination of RALPN for select renal tumors.

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Figure 1.

(A) Laparoscopic renal parenchymal clamp. It has a 37-cm working length, including the ratchet handle. Inset shows the 10-cm jaw. (B) Port placement for left-sided partial nephrectomy in morbidly obese patient using lateral camera placement (white arrow). Patient's head is to the left, and the umbilicus is shown (x). Left and right robotic ports are shown (double white arrow). Two assistant ports are shifted laterally from midline because of body habitus. Inferior assistant port (black arrow) can be used for parenchymal clamp or Satinsky clamp. (Color version available online.)

Table 1

Preoperative patient and tumor characteristics

Characteristic	Hilar	Parenchymal	P Value
Age, mean (range), y	57.2 (21.4–84.2)	53.6 (29.3–65.2)	.29
Sex (%)			
Male	19 (53)	7 (47)	.76
Female	17 (47)	8 (53)	
BMI, mean (range), kg/m ²	31.7 (20.6–49.6)	28.6 (21.2–42.4)	.15
ASA classification (%)			
II	19 (53)	9 (60)	.76
III	17 (47)	6 (40)	
Laterality (%)			
Left	13 (36)	7 (47)	.35
Right	23 (64)	8 (53)	
Mass location (%)			
Upper	10 (28)	1 (7)	.09
Interpolar	17 (47)	6 (40)	
Lower	9 (25)	8 (53)	
Radiologic mass size, median (range, SD), cm	2.8 (1.1–5.5, 1.2)	2.8 (1.4–6.1, 1.5)	.93
Pathologic mass size, median (range, SD), cm	2.5 (0.6–4.8, 1.1)	2.5 (1.0–5.5, 1.3)	.90
RENAL nephrometry score (%)			
Mild complexity (4–6)	23 (69)	12 (80)	.65
Moderate complexity (7–9)	15 (29)	3 (20)	
High complexity (10–12)	1 (2)	0 (0)	

ASA, American Society of Anesthesiologists; BMI, body mass index; SD, standard deviation.

Table 2

Perioperative and oncologic outcomes

Characteristic	Hilar	Parenchymal	P Value
Operative time, median (range), min	320 (181–535 [*])	245 (181–303)	<.0001
Clamp time, median (range), min	26 (12–45)	18 (4–38)	<.001
Estimated blood loss, mean (range), mL	217 (10–1000)	128 (20–400)	.16
Need for blood transfusion (%)	1 (3)	1 (7)	.60
Conversion to open	0 (0)	0 (0)	
Hospital stay, mean (range), d	2.8 (2–5)	3.0 (2–6)	.63
JP drain duration, mean (range), d	4.5 (1–10)	4.1 (2–9)	.58
Urinoma	0 (0)	0 (0)	
Serum creatinine, median (range), mg/dL			
Preop to POD1	0.2 (–0.2 to 0.7)	0.1 (–0.1 to 0.3)	.01
Preop to POD2	0.2 (–0.4 to 1.6)	0.0 (–0.3 to 0.2)	<.01
Preop to last follow-up	0.1 (–0.2 to 1.0)	0.0 (–0.1 to 0.2)	.18
Estimated GFR, median (range), mL/min/1.73 m ²			
Preop to POD1	–18 (–80 to 19)	–3 (–20 to 21)	<.05
Preop to POD2	–18 (–82 to 38)	0 (–13 to 25)	.02
Preop to last follow-up	–6 (–80 to 31)	–7 (–22 to 16)	.35
Primary pathology (%)			
Benign	11 (31)	3 (20)	.51
Malignant	25 (69)	12 (80)	
Fuhrman grade			.26
1	3 (8)	5 (33)	
2	18 (50)	6 (40)	
3	2 (6)	1 (7)	
4	1 (3)	0 (0)	
Secondary pathology (%)			
Clear cell	20 (56)	9 (60)	.92
Papillary I	1 (3)	0 (0)	
Papillary II	2 (6)	2 (13)	
Chromophobe	2 (6)	1 (7)	
Reninoma	1 (3)	0 (0)	
AML	4 (11)	2 (13)	
Oncocytoma	6 (17)	1 (7)	
Positive margins (%)	3 (8)	0 (0)	.26
Last follow-up, median (range), mo	6.5 (0.1–40.9)	6.8 (0.2–19.7)	.90
Last imaging follow-up, median (range), mo	6.5 (0.0–31.7)	6.6 (0.0–19.7)	.96
Tumor recurrence on follow-up (%)	0 (0)	0 (0)	

AML, angiomyolipoma; GFR, glomerular filtration rate; JP, Jackson-Pratt; POD, postoperative day.

* One patient underwent simultaneous laparoscopic adrenalectomy.

Table 3

Postoperative complications by Clavien score

Group	Clavien Score	Organ System	Notes
Hilar (9/36)	1	Neurologic (2)	Flank pain requiring postoperative readmission
		Urinary	Failed initial voiding trial, but passed next day (McDonald)
		GI	Ileus requiring nasogastric tube and prolonged hospitalization
		Wound	Superficial wound dehiscence and healing by secondary intention
		Pulmonary	Shortness of breath with negative workup
	2	Cardiovascular	Overnight ICU stay for hypotension requiring transfusion
		Urinary	Admission for pyelonephritis with admission
Pole clamp (4/15)	3b	Musculoskeletal	Port site hernia with anticipated repair
	1	GI	Ileus with prolonged hospitalization without requiring nasogastric tube
	2	Urinary	Nonfebrile UTI
	3a	Renal	Perinephric hematoma requiring embolization and transfusion
	3b	Musculoskeletal	Port site hernia at extraction site with elective repair

GI, gastrointestinal; ICU, intensive care unit; UTI, urinary tract infection.