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Robotic-assisted laparoscopic partial nephrectomy: initial experience in Brazil and a review of the literature

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ABSTRACT

Context and Purpose: Partial nephrectomy has become the standard of care for renal tumors less than 4 cm in diameter. Controversy still exists, however, regarding the best surgical approach, especially when minimally invasive techniques are taken into account. Robotic-assisted laparoscopic partial nephrectomy (RALPN) has emerged as a promising technique that helps surgeons achieve the standards of open partial nephrectomy care while offering a minimally invasive approach.
The objective of the present study was to describe our initial experience with robotic-assisted laparoscopic partial nephrectomy and extensively review the pertinent literature.
Materials and Methods: Between August 2009 and February 2010, eight consecutive selected patients with contrast enhancing renal masses observed by CT were submitted to RALPN in a private institution. In addition, we collected information on the patients' demographics, preoperative tumor characteristics and detailed operative, postoperative and pathological data. In addition, a PubMed search was performed to provide an extensive review of the robotic-assisted laparoscopic partial nephrectomy literature.
Results: Seven patients had RALPN on the left or right sides with no intraoperative complications. One patient was electively converted to a robotic-assisted radical nephrectomy. The operative time ranged from 120 to 300 min, estimated blood loss (EBL) ranged from 75 to 400 mL and, in five cases, the warm ischemia time (WIT) ranged from 18 to 32 min. Two patients did not require any clamping. Overall, no transfusions were necessary, and there were no intraoperative complications or adverse postoperative clinical events. All margins were negative, and all patients were disease-free at the 6-month follow-up.
Conclusions: Robotic-assisted laparoscopic partial nephrectomy is a feasible and safe approach to small renal cortical masses. Further prospective studies are needed to compare open partial nephrectomy with its minimally invasive counterparts.

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INTRODUCTION

The ubiquitous use of abdominal imaging modalities has resulted in an increase in the detection of incidental small renal masses (1). Surgical extirpation, especially open partial nephrectomy (OPN), is still the preferred treatment for small renal masses. Indeed, surgical extirpation is an established treatment for solid or complex cystic small renal masses, and it has oncologic control

Table 1 - Patient Demographics.

Variable	Mean (range) or number
Age, years	58.25 (35-76)
Gender (male/female)	5/3
ASA Score	1.75 (1-3)
BMI, Kg/m^2	27 (21.1-33.3)
Tumor side	
Left	3
Right	5
Tumor size on CT (mm)	23 (12-38)
Preoperative creatinine (mg/dL)	1.03 (0.7-1.47)
Preoperative hemoglobin (g/dL)	12.6 (11.2-13.6)
Tumor Location	
Upper pole	1
Mid-pole	2
Lower pole	5
Tumor classification	
Endophytic	1
Exophytic	7
Previous abdominal surgery (yes/no)	2/6

comparable to that of radical nephrectomy (2). Furthermore, favorable outcomes and safety data suggest that patients who undergo partial nephrectomy have better renal function and are less likely to require renal replacement therapy than patients who undergo radical nephrectomy (3,4).

Because of the added morbidity of an open procedure, laparoscopic partial nephrectomy (LPN), which has demonstrated comparable perioperative and convalescent benefits, has emerged as a viable alternative to OPN (5). Unfortunately, LPN is technically challenging, and there is disagreement over the extent of problems related to renal function due to the long periods of ischemia required for tumor excision and intracorporeal sutured reconstruction (6).

In the past decade, many centers have successfully incorporated the da Vinci® robotic system in an attempt to perform complex reconstructive procedures with more precision, dexterity and rapidity. This system offers the surgeon an invaluable minimally invasive tool to overcome every challenge of LPN and preserve long-term renal function (7). We present our initial experience in robotic-assisted laparoscopic partial nephrectomy (RALPN) from a private institution in Brazil. In addition, we performed a detailed review of the pertinent literature.

MATERIALS AND METHODS

Between August 2009 and February 2010, eight consecutive patients (five males and three females) with enhancing renal masses observed by computed tomography (CT) were submitted to robotic-assisted renal surgery in a private institution. All patients had their surgery performed by the same surgeon. The patient demographics and preoperative tumor characteristics are presented in Table-1. There were no cases with multiple renal tumors or previous renal surgery. Operative data included the operative time (from the time the robot was docked to drain placement), estimated blood loss (EBL), warm ischemia time (WIT) and intraoperative complications. The postoperative data included postoperative creatinine and hemoglobin values two days after surgery (but before discharge), length of stay, adverse clinical or surgical events (perinephric hematoma and urinary leakage), and the need for morphine derivatives. The pathology results were reviewed for tumor type, tumor size and margin status. A CT scan at the 6-month follow-up was indicated depending upon individual patient pathology.

We also performed a PubMed search using the terms laparoscopic surgery, partial nephrectomy and robotic-assisted, and we compiled a detailed review of the pertinent literature. All articles with a series of patients were included.

RALPN Technique

The patients were placed in the flank position with the operative side facing up, and the operating table was partially flexed. The abdomen was insufflated with CO^2 via transperitoneal Veress needle access to a maximum pressure of 15 mmHg. The da Vinci® (Intuitive Surgical, Sunnyvale, CA) robot was then docked, and the entire procedure was performed robotically. Thirty-degree lens facing the down position were used in all cases. No ureteral catheters were placed.

After insufflation was observed, the colon was reflected medially, and the kidney was exposed from the lower pole to the upper pole. Gerota's fascia was dissected over the kidney, and the lesion was identified. In all cases but one (in which it was electively decided to convert to a radical robotic-assisted procedure because of tumor location), a robotic-assisted partial nephrectomy was performed. In all but two cases, which did not require hilar clamping, either the main artery or a polar artery was individualized for bulldog clamping. Laparoscopic bulldog clamps were placed across the full length of the renal arteries by the bedside surgeon.

Hot scissors were used to excise the mass, and all lesions were sent to pathology to create frozen sections. The collecting system was repaired with 3-0 polyglactin sutures in two cases. For renal reconstruction, we used a 2-0 polyglactin suture, which was placed through the capsule of the kidney and sequentially through the parenchyma of the operative bed (parenchymal sutures). Additional 0 polyglactin sutures were placed through the renal capsule and tied over a Surgicel bolster (capsular sutures). After releasing the bulldog clamp, intra-abdominal pressure was lowered to 5-10 mm Hg, and the operative field was carefully inspected. The tumor was placed in an organ bag, and a 15F Jackson-Pratt drain was placed around the kidney.

RESULTS

Perioperative data and final pathologic information are depicted in Tables 2 and 3, respectively. Three patients underwent RALPN on the left side, and four patients underwent RALPN on the right side. None of these patients had any intraoperative complications. One patient had a centrally located endophytic tumor near the renal hilar vessels. After hilum dissection and tumor exposure, we decided to electively convert the procedure to a robotic-assisted radical nephrectomy, which was conducted without any difficulties. Tumor sizes ranged from 15 to 35 mm, and most of the lesions were lower pole and exophytic cortical lesions. Operative time ranged from 120 to 300 min, EBL ranged from 75 to 400 mL and WIT ranged from 18 to 32 min (Table-2). There were no transfusions needed, no intraoperative complications and no adverse postoperative clinical events. In addition, hospital stays were only two to three days. Three patients required morphine derivatives, but only until the day after surgery. Four patients had renal cell carcinomas, grade 2 to 3. One patient (number 7) had his nephrectomy bed resection

Table 2 - Perioperative variables.

Variable	Mean (range) or number
ORT (min.)	216.25 (120-300)
EBL (mL)	213.125 (75-400)
Pelvicalycial system repair	2
WIT (min)	
Artery only	4 cases 24 min (18-32)
Polar artery	1 case 23 min
No clamping	2 cases
N/A	1
Postoperative creatinine (mg/dL)	1.12(0.78-1.52)
Conversion	1
Transfusion	0
Postoperative hemoglobin (g/dL)	11.7(10.5-13.1)
Postoperative Hospital stay (days)	2.37(2-3)
Intraoperative complications	0
Adverse clinical postoperative events	0
Postoperative morphine derivatives use	2
Perinephric hematoma	0
Urinary leak	0

ORT, operative time; **EBL**, estimated blood loss; **WIT**, warm ischemia time; **N/A,** not appplicable

margin ampliated, and all pathological data of the final margins showed negative results in our series. There was one complex Bosniak category III cyst observed by a preoperative CT scan, but it turned out to be benign. We also observed one angiomyolipoma, which was indistinguishable from renal cell carcinoma on the preoperative CT scan, and two oncocytomas. Importantly, there were no recurrences at the six-month follow-up.

DISCUSSION

The initial series of RALPN included patients with tumors ranging in size from 1 to 7.5 cm (the mean tumor size was 2.98 cm). The mean operative time, EBL and mean WIT are depicted in Table-4. Generally, the authors used a four-arm da Vinci® robotic system with a transperitoneal approach with regular hilum clamping and warm ischemia, with the robot docked at the begginning of the procedure.

Gettman et al. described one patient at the Mayo Clinic who experienced a positive margin, but there were no recurrences. Although one patient of the 13 in his series had prolonged ileus, there were no other significant postoperative complications (8). In another study, Kaul et al. described a slightly different lateral camera configuration with a 30° down lens during the operation; however, they still used an initial robotic-assisted approach. The Kaul et al. study reported 2 complications: one urinary leak, which was responsible for the long length of hospital stay shown in Table-4, and one re-exploration for bleeding (9). Ho et al. was the only group that used a tourniquet technique, which ensures that vascular control remains with the console surgeon. Every patient in the Ho et al. study was followed for at least 12 months, and no recurrences were observed (10).

Bhayani and Das reported their initial experiences with a different sliding-clip renorrhaphy (i.e., Hem-O-Lock clips). The Hem-O-Lock clips slide into place under complete control of the surgeon seated at the console and are secured with a LapraTy clip (11,12). In the Bhayani and Das study, one patient was converted to open partial nephrectomy when the margins were not clear during intraoperative ultrasound, and another patient was converted to robotic-assisted cryoablation without complications (11).

The largest series of partial nephrectomy patients, which was published by Rogers et al., included 148 patients from six institutions. In these selected patients, surgery was performed by experienced laparoscopic urologists. There were only two conversions to OPN, and there were no long-term recurrences in their casuistics (13). There have been multiple studies involving the use of RALPN for complex and challenging cases, and detailed results are depicted in Table-5. Neither conversions nor recurrences have been reported in the studies describing RALPN (14-16).

A highly experienced group has recently published their initial cases of partial nephrectomy without vascular hilar clamping, which minimized the risk of vascular injury and kidney ischemia associated with temporary arterial occlusion. The lack of vascular hilar control, however, resulted in a higher mean EBL compared with other contemporary series (Table-5) (17).

Current studies that compared LPN and RALPN are depicted in Table-6. Unfortunately, there are no randomized, controlled, prospective studies with adequate follow-up periods. A study by Caruso et al. in 2006 was the first observational study to compare LPN and RALPN, and they did not find any significant differences in operative time, ischemic time, EBL or hospital stay between the two groups (Table-6) (18).

A retrospective, case-matched comparison study that used an early unclamping technique in LPN and RALPN patients found that WIT was significantly higher for the RALPN group (21 vs. 14 minutes, $p < 0.05$); however, this study was limited by the small number of patients. Therefore, the results for WIT with the early unclamping technique were inconclusive (19). More recent studies have shown that WIT has been reduced as doctors gain more experience with RALPN. Their analysis demonstrated that RALPN resulted in shorter operative times, WITs and lengths of hospital stay compared with LPN (Table-6) (20-22).

The present study was the first robotic-assisted renal surgery series in Brazil. There are several inherent limitations of the present study because it was a prospective study with a small cohort of highly selected patients (with no control arms) who were only followed for a short period of time. Nevertheless, the present study was able to show that RALPN is a safe and feasible option for the

Table 3 - Pathologic data.

Variable	Mean (range) or number
Tumor size (mm)	24.37(15-35)
Positive surgical margins	0
Malignant Tumor histology	
Clear cell	4
Papillary	0
Chromophobe	0
Microvascular invasion	0
Clear cell grade	
1	0
2	3
3	1
Benign Tumors	
Oncocytoma	2
Angiomyolipoma	1
Cyst	1

Table 4 - Initial RALPN series.

Parameter	Gettman et al. (8)	Kaul et al. (9)h	Ho et al. (10)	Bhayani and Das (11)	Rogers et al. (13)
No RALPN	13	10	20	35	148
Mean Tumor size / range (cm)	3.5 (2 - 6)	2.3 (1-3.5)	3.5 (2.5-5)	2.8 (1-6)	2.8 (0.8-7.5)
Mean ORT (range), min	215 (130 - 262)	155 (120 - 185)	82.8 (75 - 95)	142 (69 - 219)	19 (63-392)
Mean EBL (range), mL	170 (50 - 300)	92	189 (50 - 260)	133 (25 - 500)	183 (15 - 1000)
Mean WIT (range), min	22 (15 - 29)	21 (18 - 27)	21.7 (15 - 27)	21 (0 - 40)	27.8 (12 - 60)
Positive margins	1	0	0	0	6
Mean LOS (range), days	4.7 (2 - 7)	3.5 (1 - 21)	4.8 (4 - 7)	2.5 (1 - 7)	1.9 (1 - 7)
Recurrence	0	0	0	0	0
No of complications	1	2	0	4	9

RALPN, Robotic-assisted laparoscopic partial nephrectomy; **ORT**, operative time; **EBL**, estimated blood loss; **WIT**, warm ischemia time; **LOS**, length of hospital stay

Table 5 - RALPN for complex tumors.

Parameter	Rogers et al. (14)	Rogers et al. (15)	White et al. (17)
No RALPN	8(14 tumors)	11	8
Mean Tumor size / range (cm)	2.3 (1.5 - 5)	3.8 (2.6 - 6.4)	2.38 (1.1 - 3.5)
Mean ORT (range), min	192 (165 - 214)	202 (154 - 253)	167 (118 - 215)
Mean EBL (range), mL	230 (100 - 450)	220 (50 - 750)	569 (250 - 2000)
Mean WIT (range), min	31(24 - 45)	28.9 (20 - 39)	0
Positive margins	0	0	0
Mean LOS (range), days	2.6(2 - 3)	2.6 (1 - 4)	3.75 (3 - 5)
Recurrence	0	0	0
No of complications	0	2	2

RALPN, Robotic-assisted laparoscopic partial nephrectomy; **ORT,** operative time; **EBL,** estimated blood loss; **WIT,** warm ischemia time; **LOS**, length of hospital stay

Table 6 - Robotic versus Laparoscopic Partial Nephrectomy.

Parameter (RALPN vs LPN), p value	Caruso et al. (18)	Aron et al. (19)	Wang and Bhayani (20)	Deane et al. (21)	Kural et al. (22)
No RALPN	10	12	40	11	11
No LPN	10	12	62	11	20
MTS, cm	(1.95 vs 2.18), 0.46	(2.4 vs 2.9), 0.06	(2.5 vs 2.4), NS	(3.1 vs 2.3), NS	(3.2 vs 3.1), 0.85
Mean ORT, min	(279 vs 253), 0.11	(242 vs 256), 0.60	(140 vs 156), 0.04	(228.7 vs 289.5), 0.10	(185 vs 226), 0.07
Mean EBL, mL	(240 vs 200), 0.9	(329 vs 300), 0.84	(136 vs 173), NS	(115 vs 198), 0.16	(286.4 vs 287.5), 0.3
Mean WIT, min	(26.4 vs 29.3), 0.24	(23 vs 22), 0.89	(19 vs 25), 0.03	(32.1 vs 35.3), 0.50	(27.3 vs 35.8), 0.02
Positive margins	(0 vs 1)	0 vs 0	1 vs 1	0 vs 0	(0 vs 1)
Mean LOS, days	(2.6 vs 2.65), 0.89	(4.7 vs 4.4), 0.77	(2.5 vs 2.9), 0.03	(2.0 vs 3.1), 0.04	(3.9 vs 4.27), 0.28
Recurrence	NA	0	0	0	0
No of complications	5	3	17	2	4

management of selected small renal tumors. Furthermore, our operative time, EBL and WIT results were comparable to those of previous RALPN studies, which was particularly encouraging because the present series reflects our initial experience with robotic assistance for renal surgery.

Although OPN is currently considered to be the standard of care for the treatment of small renal tumors, intermediate oncologic outcomes for LPN are also excellent (23), and it is likely that oncologic outcomes are comparable between OPN, LPN and RALPN. Ischemic time is a major concern for renal function preservation, but this may not be an issue with RALPN because clamping times are less than 20 min and because RALPN also uses parenchymal clamping. Similar to LPN, RALPN causes less postoperative pain and decreases the length of hospitalization and active recovery.

CONCLUSIONS

Robotic-assisted laparoscopic partial nephrectomy is a feasible and safe approach to remove small renal cortical masses amenable to partial nephrectomy. Our impression is that robotic assistance may facilitate a minimally invasive, nephron-sparing approach for select patients with renal cortical tumors who might otherwise require open surgery or radical nephrectomy. Further well-conducted, prospective, randomized trials are needed to compare open partial nephrectomy with its robotic counterpart.

ABBREVIATIONS

RALPN: Robotic-assisted laparoscopic partial nephrectomy;
LPN: Laparoscopic partial nephrectomy;
MTS: Mean tumor size;
ORT: Operative time;
EBL: Estimated blood loss;
WIT: Warm ischemia time;
LOS: Length of hospital stay;
NA: Not available;
NS: Not significant

CONFLICT OF INTEREST

None declared.

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