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ORIGINAL ARTICLE

Robotic-assisted partial nephrectomy provides better operative outcomes as compared to the laparoscopic and open approaches: results from a prospective cohort study

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Abstract The objective of this is to compare the surgical outcomes of partial nephrectomy (PN), performed via three different approaches: robot-assisted (RAPN), laparoscopic (LPN), and open (OPN), in a single non-academic regional center. The data of patients undergoing PN at our Department from 2005 to 2016 were prospectively collected. A logistic regression model adjusted for preoperative variables (age, tumor size, creatinine and hemoglobin, ASA and Padua scores) was performed to evaluate whether transfusion, conversion, and postoperative complication rate were influenced by the surgical approach. Overall 270 patients underwent PN: analysis included 253 cases (RAPN = 110, LPN = 70, OPN = 73). Preoperative variables did not differ significantly among the three groups. Shorter operative (130 vs 180 and 200′) and ischaemia (12 vs 23 and 22′) times and longer hospital stay (8 vs 7 and 6 days) were found in the OPN group as compared to LPN and RAPN, respectively. The RAPN group included a higher rate of pT1b (31.8 vs 14.2 and 15%) and malignant histotype (90 vs 82.9 and 68.5%) as compared to LPN and OPN, respectively. Clavien Grade III–IV complications were lower in the RAPN (7.2%) as compared to OPN (12.3%) and LPN (17.1%) groups. Multivariate analysis showed a lower risk for conversion, transfusion and overall complications in the RAPN group versus LPN and OPN. The surgical approach affects the perioperative outcomes in a regional setting. The advantages of RAPN over OPN (lower risk of conversion, transfusion, and overall complications) are extended over LPN as well, although OPN offered faster operative and ischemia times at the expense of greater blood loss and hospital stay.

Keywords Carcinoma renal cell · Nephrectomy · Partial · Robotics · Laparoscopy · Open · Operative outcomes

Introduction and objectives

Localized T1a-b renal tumors are best managed by partial nephrectomy (PN), rather than radical nephrectomy, if technically feasible, irrespective of the surgical approach [1, 2]. However, in the light of the strong evidence of the procedure's benefit it is considered underutilized [3, 4], although more recent reports have suggested that use of robotic technology was associated with increased utilization of partial nephrectomy [5]. Specifically, hospital acquisition of the surgical robot facilitated increased utilization of a guideline-supported procedure [6].

Preoperative characteristics such as age, medical comorbidities, tumor size and configuration make difficult and influence comparisons between treatment modalities. In fact, only a few studies with an adequate number of patients compare robotic (RAPN) versus open (OPN) [7, 8] and robotic versus laparoscopic partial nephrectomy (LPN) [9–11]. Even fewer studies compare these three approaches currently available [12, 13]. The objective of our study is to evaluate the functional and oncologic outcomes of PN performed with the above-mentioned approaches at a single regional hospital.

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Materials and methods

Study design and data collection

The data of patients undergoing PN at our Department from January 2005 to June 2016 were prospectively collected. Data regarding preoperative clinical characteristics, intra- and postoperative data were collected in a dedicated database and compared. The surgical approach depended on the technique used at our Department at that time: OPN was the standard from 2005 to 2008, LPN from 2009 to 2011, and RARP from 2012 until now. OPN is still seldom performed in anesthesiologically high-risk patients. All surgeries were performed by a single surgeon (GM) with extensive open and laparoscopic experience.

Preoperative evaluation and data collection

For each patient, we prospectively collected preoperative [age, serum creatinine, American Society of Anaesthesiologists (ASA) score, Padua score, tumor side], perioperative (operative and ischemia time, blood loss, peri- and postoperative complications within 30 days, hospital stay) and pathologic data (histotype, tumor size, Fuhrman nuclear grade, surgical margin status). Medical and surgical complications were collected for all patients through a combination of institutional electronic medical records and operative notes. Padua score was assigned by one single attending physician the day before surgery [14]. Tumor size was assessed as the maximum diameter of the pathologic specimen. Routine preoperative radiographic imaging included chest X-ray imaging and abdominal computed tomography (CT) scan. MRI was used in a few patients as an alternative to CT. Bone scans and brain CT were obtained only when indicated by the signs and symptoms. Complications were prospectively recorded according to the Clavien–Dindo classification [15]. Patients were usually transfused in case of hemoglobin level below 8 g/dL in healthy and below 9 g/dL in patients with ischemic cardiac disease.

Short description of surgical techniques

OPN

Flank incision for retroperitoneal approach or Chevron incision for transperitoneal approach based on the location of the renal mass was utilized for all patients. Tumor excision was done by clamping the renal artery with a bulldog clamp or with no clamping, using manual compression of the surrounding renal parenchyma. Opened calyces and bleeding sites were sutured and the parenchymal defect was closed with horizontal interrupted sutures with or without the application of haemostatic agents.

LPN

The laparoscopic approach included modified flank position and a three- to four-port method of transperitoneal nephrectomy. A pneumoperitoneum of 12 mmHg was created by open access. If the collecting system had been entered, or if large vessels remained patent, a repair with absorbable suture materials was made before proceeding with a renorrhaphy, in a fashion similar to the open technique.

RAPN

The RAPN technique is extensively described in a previous paper [16]. Patients were positioned in full flank position. Pneumoperitoneum was created by open access. RAPNs were performed through a transperitoneal approach by use of a 5-trocar technique. A robotic fourth-arm approach became routinary after 50 cases. After hilar clamping, the tumor was resected along a previously scored margin using cold resection with the robotic monopolar scissors. Hemostasis is achieved using a combination of cautery, suturing (double layer) with sliding clip technique [17], and hemostatic agents.

Statistics

Distribution of continuous variables are reported as median and interquartile range (IQR) (25th; 75th percentiles) and as mean and standard deviation (SD). Categorical variables are presented as numbers and percentages. The comparison between subgroups (surgical approach) was performed using Student t test or Mann–Whitney U test for continuous variables. Qualitative data were compared by the χ^2 test or Spearman correlation. Univariate and multivariate analysis was performed by the logistic regression model to evaluate significant predictors of transfusion, conversion, and postoperative complication rates; odds ratios (OR) and 95% confidence interval (95% CI) were calculated. The regression model was calculated adjusting for preoperative and postoperative data (age, tumor diameter, pT stage, Fuhrman grading). P values were considered significant when less than or equal to 0.05. All tests were two sided. All analyses were performed using the SPSS software (IBM Corp., Armonk, NY, USA).

Results

Preoperative characteristics

Overall, 270 patients underwent RAPN (127), OPN (73) or LPN (70) between January 2005 and June 2016 at the

Table 1 Preoperative characteristics of patients and tumors stratified according to surgical approach

Preoperative variables	RAPN ($n = 110$)	LPN ($n = 70$)	OPN ($n = 73$)	p value	
				RAPN vs OPN	RAPN vs LPN
Sex F/M	43/67	28/42	22/51	0.270	0.903
Age (ys)				0.354	0.848
Median (IQR)	62.8 (51.7–71.6)	62.9 (56–69.5)	65 (54.7–72.6)		
Mean (SD)	61 (12)	62 (11)	63 (13)		
Tumor size (cm)				0.966	0.584
Median (IQR)	3.5 (2.5–4.8)	3.5 (2.5–4)	3.0 (2.5–4)		
Mean (SD)	3.6 (1.5)	3.5 (1.4)	3.6 (2.3)		
ASA score (%)				0.116	0.502
1	9 (8.2)	1 (1.4)	10 (13.7)		
2	80 (72.7)	63 (90)	54 (74)		
3	21 (19.1)	6 (8.6)	9 (12.3)		
Side L/R	58/50	35/35	34/39	0.511	0.467
Bilateral	2	0	0		
Padua score (%)				0.576	0.764
6–7	52 (47.3)	32 (45.7)	40 (54.8)		
8–9	43 (39.1)	27 (38.6)	22 (30.1)		
≥10	15 (13.6)	11 (15.7)	11 (15.1)		
Pre-Hb (g/dL)				0.03	0.342
Median (IQR)	14.4 (13.3–15.1)	14.2 (12.9–15.2)	13.8 (13–14.9)		
Mean (SD)	14.2 (1.5)	13.9 (1.7)	13.7 (1.5)		
Pre-creat (mg/dL)				0.111	0.77
Median (IQR)	0.9 (0.8–1)	0.8 (0.7–1)	0.9 (0.9–1.1)		
Mean (SD)	1.0 (0.4)	0.9 (0.5)	1.1 (0.4)		

Department of Urology of Trento. The data regarding the last 17 RAPNs are not yet available, making the analysis possible on 253 cases (RAPN = 110), (OPN = 73) and (LPN = 70). Patients' demographics and preoperative characteristics are reported in Table 1. Age and mean hemoglobin levels were similar among the three groups. Tumor diameter was similar between LPN and RAPN groups, whereas it was lower in the OPN group. Patients undergoing RAPN had a higher rate of pT1b RCC as compared to LPN and OPN groups. Adrenalectomy was associated with PN in eight cases (RAPN = 1, LPN = 2, OPN = 5). No lymphadenectomy was performed.

Operative and perioperative results

Operative and perioperative data are shown in Table 2. Median operative time was significantly shorter in the OPN group as compared to LNP and RAPN (130′ vs 180′ vs 200′). Median EBL was significantly lower in the RAPN as compared to the OPN and LPN groups (150 vs 200 and 200 ml) as well as the transfusion rate (10 vs 21.4 vs 21.9%). The conversion rate was statistically higher in the LPN as compared to the RAPN group (5.5 vs 8.6%). Hospital stay was statistically shorter in the RAPN as compared to the other two surgical techniques. Pathological T1b rate was 31.8, 14.2, and 15%, in the RAPN, LPN, and OPN groups, respectively. A malignant histotype was assessed in 90, 82.9, and 68.5%, in the RAPN, LPN, and OPN groups, respectively. Pathological features are shown in Table 3.

Complications

The complications according to the Clavien–Dindo classification are summarized in Table 4, including the type of complications and its management. Grade I complications were similar in the three groups and included pain and transient fever. Grade II complications were statistically lower in RAPN as compared to OPN and LPN (11 vs 20.5 vs 16%). The rate of Grade III–IV complications was also lower in the RAPN group (7.2%) as compared to OPN (12.3%) and LPN (17.1%) groups. No Grade V complications were reported.

Table 2 Operative and perioperative data stratified according to the different surgical approach

Perioperative variables	RAPN ($n = 110$)	LPN ($n = 70$)	OPN ($n = 73$)	p value	
				RAPN vs OPN	RAPN vs LPN
WIT (min)				<0.0001	<0.0001
Median (IQR)	22 (0–45)	23 (0–45)	12 (0–20)		
Mean (SD)	23 (9)	16 (12)	4 (6)		
Operative Time (min)				<0.0001	0.003
Median (IQR)	200 (120–385)	180 (105–346)	130 (45–315)		
Mean (SD)	209 (53)	186 (49)	145 (59)		
Blood loss (cc)				0.510	0.103
Median (IQR)	150 (0–900)	200 (0–1500)	200 (0–1700)		
Mean (SD)	245 (267)	316 (307)	275 (362)		
Post Hb (g/dL)				0.160	0.780
Median (IQR)	11.4 (8–15.3)	11.3 (9.4–15)	10.7 (8.5–16)		
Mean (SD)	11.5 (1.4)	11.4 (1.3)	11.2 (1.5)		
Post Cr (mg/dL)				0.378	0.033
Median (IQR)	1 (0.3–4.2)	0.9 (0.5–2.9)	1 (0.6–3.4)		
Mean (SD)	1.1 (0.6)	1 (0.4)	1.2 (0.5)		
Hospital stay (days)				<0.0001	0.003
Median (IQR)	6 (4–22)	7 (4–23)	8 (5–30)		
Mean (SD)	6 (3)	8 (3)	9 (5)		

Table 3 Pathological features stratified according to the different surgical approach

Pathological features	RAPN ($n = 110$)	LPN ($n = 70$)	OPN ($n = 73$)
Benign tumors	11 (10%)	12 (17.1%)	23 (31.5%)
Tumor stage			
pT1a	64	48	35
pT1b	35	10	11
pT2	0	0	1
pT3a	0	0	2
Fuhrman grade			
1	37	12	15
2	47	33	15
3–4	7	4	10
Positive margins	7 (6.3%)	3 (4.2%)	0

Comparative results adjusted for patients characteristics

The results of the univariate and multivariate analysis adjusted for preoperative variables are shown in Table 5 (RAPN versus LPN and RAPN versus OPN). The risk of transfusion and conversion is significantly lower in the RAPN group as compared to the LPN and OPN groups. RAPN is also associated with a significantly lower risk of complications as compared to the OPN group and with a trend in favor of RAPN as compared to LPN.

Discussion

Partial nephrectomy (PN) is the gold standard for treatment of small renal masses, whenever technically feasible, as recommended by international guidelines [1, 2]. For many years open surgery represented the best and exclusive approach for PN. In recent years, LPN and RAPN have been recommended as these techniques minimize the invasiveness of open surgery. RAPN allows enhanced precision with shortened surgical learning curve, operative and ischaemic times with less blood loss compared with LPN. Moreover, also because of the

Table 4 Complications according to the Clavien–Dindo classification stratified according to the different surgical approach

Complications grading	RAPN ($n = 110$)	LPN ($n = 70$)	OPN ($n = 73$)
Grade I			
Prolonged pain	2	1	
Fever	2	2	
Pleural effusion	3		
Hepatic effusion			1
Transient diarrhea			1
Grade II			
Need for blood transfusion	11	15	16
Pulmonary consolidation	3		1
Renal hematoma	1	2	
TVP	1		1
Grade III			
Post-op bleeding requiring radiological embolization	3	2	1
Post-op bleeding requiring surgical revision	2	3	3
Urinoma requiring ureteral stent placement	3	6	5
Grade IV			
Life-threatening complication requiring critical care management	/	1	/
Grade V	/	/	/

Table 5 Univariate and multivariate analysis using a logistic regression model to evaluate the risk of transfusion, overall complications and conversion after RAPN versus LPN and RAPN versus OPN unadjusted and adjusted for preoperative data (sex, age, tumor diameter, ASA and Padua score)

	RAPN vs LPN unadjusted	RAPN VS LPN adjusted	RAPN vs OPN unadjusted	RAPN vs OPN adjusted
Transfusion (OR; 95% CI)	2.45 (1.05–5.71)	2.95 (1.18–07.37)	2.52 (1.09–5.81)	3.11 (1.27–7.61)
	p 0.037	p 0.021	p 0.029	p 0.013
Overall complications (OR; 95% CI)	1.75 (0.89–3.43)	1.88 (0.93–3.80)	1.75 (0.90–3.41)	2.08 (1.02–4.21)
	p 0.102	p 0.078	p 0.098	p 0.042
Conversion (OR; 95% CI)	0.75 (0.22–2.55)	0.63 (0.16–2.40)	–	–
	p 0.64	p 0.50		

steep learning curve of LPN, few centers succeeded to improve a structured program with high caseloads, and RAPN is displacing all other surgical approaches.

The evolution of the approach to PN is well reflected at our Department, where the transition to RAPN occurred after 3 years of LPN as a standard of care: from the beginning of 2012, the pure LPN has been supplanted by the robotic approach. Several studies compared the surgical outcomes of the three approaches to PN, mainly as a one-to-one comparison of OPN versus LPN or OPN versus RAPN. Few studies only reported the results of the three approaches in single academic and non-academic institutions reporting a relatively low or non-homogeneously distributed number of patients among the three techniques [12] or from multicenter series [13]. Our study compares the outcomes of a series of consecutive patients at a single regional hospital, utilizing a logistic regression model to control the differences in baseline demographic and pathologic data among cohorts.

In our study, the median EBL was significantly lower in the RAPN as compared to the OPN and LPN groups (150 vs 200 vs 200 ml, respectively), as well as the rate of transfusion (10 vs 21 vs 21%), confirming previous results: a transfusion rate of 6 and 15% after a mini-invasive approach (RAPN or LPN) and OPN, respectively [18].

Another parameter supporting the benefit of the intuitive nature of the robotic technique is the rate of conversion to open surgery. In fact, although relatively uncommon, a life-threatening bleeding might require an emergent conversion to an open procedure. Previous studies report conversion rates of 1.9–4.5% for LPN and 1.6–1.9% for RAPN [9, 11], which is consistent with our findings (8.6 vs 5.5%).

As far as complications are concerned, grade I complications according to Clavien–Dindo were similar in the three groups, whereas grade II complications were lower in the RAPN group as compared to the OPN and LPN groups (14.5 vs 24.6 vs 24.2%); similar results were reported for grade III complications (7.2 vs 12.3 vs 15.7%). No patient undergoing PN experienced grade V complications. The overall rate of complications was significantly lower in the RAPN as respect to the OPN group and with a trend in favor of RAPN over LPN as well. Overall complication are comparable to those found in the literature: Porpiglia reported grade II and III complication rates of 5.3, 8.8, and 15.1% in RAPN, LPN, and OPN groups, respectively [13].

The positive margin rate (PMR) in our study was 6.3, 4.2, and 0%, after RAPN, LPN, and OPN, respectively. The PMR after each approach is extremely variable in the literature. Ficarra reported a similar PMR after RAPN and OPN (5.7 vs 5.5%) [7], whereas Porpiglia reported a PMR as high as 1.6–2.7% after LPN as compared to 0.8–6.8% after OPN [13]. The relatively higher PMR in our RAPN group might be explained by a higher rate of pT1b (31.8 vs 14.2% and 15%) and malignant histotype (90 vs 82.9% and 68.5%) in the RAPN group as compared to LPN and OPN.

In our study, the mean hospital stay was significantly lower in the RAPN group (6 days) as compared to LPN (7 days) as well as OPN (8 days). In previous studies, hospital stay was as high 2.5–5.2 days after RAPN versus 2.9–5.3 days after LPN [19, 20]. In general, hospital was higher than that reported in the literature, reflecting different management pathways.

After adjustment for preoperative variables, the risk of transfusion was significantly lower following RAPN as compared to either LPN or OPN. Similarly, the risk of overall complications is significantly lower following RAPN as compared to OPN and more favorable following RAPN as compared to LPN. On the other side, as far as conversion is considered, no statistically significant difference was found between RAPN and LPN.

Our study has some limitations. First, this is a non-randomized study comparing different surgical approaches. However, many patients are unwilling to be randomly assigned to a particular surgical treatment and are usually attracted by the most modern surgical procedure or chose a procedure based on personal preferences for a specific surgeon. Second, our study involved a relatively low number of patients with inherent biases related to data collection. Moreover, our series comprises the learning curve of laparoscopic and robotic PN, but not that of open PN, making the interpretation of results more intricate. On the other side, indications to surgery, operative techniques and perioperative management, and data collection should be relatively homogeneous in a single-center series. Consequently, the present study provides a realistic view of daily clinical practice.

Conclusions

In this series, we compared three cohorts of patients treated with OPN, LPN, and RAPN. OPN offered faster operative and ischemia times at the expense of greater blood loss and hospital stay. Transfusion and overall complication rates were significantly lower in the RAPN group as compared to OPN and LPN groups. Although for some respects RAPN completes the evolution of OPN to LPN, further data on oncologic follow-up are needed to establish robotics as a new standard of nephron-sparing surgery.

Compliance with ethical standards

Conflict of interest Lorenzo G. Luciani, Stefano Chiodini, Daniele Mattevi, Tommaso Cai, Marco Puglisi, William Mantovani, Gianni Malossini declare that they have no conflicts of interest.

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