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ORIGINAL ARTICLE

Comparison of perioperative outcomes following transperitoneal versus retroperitoneal robot-assisted partial nephrectomy: a propensity-matched analysis of VCQI database

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Abstract

Objective To compare perioperative outcomes following retroperitoneal robot-assisted partial nephrectomy (RPRAPN) and transperitoneal robot-assisted partial nephrectomy (TPRAPN).

Methods With this Vattikuti Collective Quality Initiative (VCQI) database, study propensity scores were calculated according to the surgical access (TPRAPN and RPRAPN) for the following independent variables, i.e., age, sex, side of the surgery, RENAL nephrometry scores (RNS), estimated glomerular filtration rate (eGFR) and serum creatinine. The study's primary outcome was the comparison of trifecta between the two groups.

Results In this study, 309 patients who underwent RPRAPN were matched with 309 patients who underwent TPRAPN. The two groups matched well for age, sex, tumor side, polar location of the tumor, RNS, preoperative creatinine and eGFR. Operative time and warm ischemia time were significantly shorter with RPRAPN. Intraoperative blood loss and need for blood transfusion were lower with RPRAPN. There was a significantly higher number of intraoperative complications with RPRAPN. However, there was no difference in the two groups for postoperative complications. Trifecta outcomes were better with RPRAPN (70.2% vs. 53%, $p < 0.0001$) compared to TPRAPN. We noted no significant change in overall results when controlled for tumor location (anteriorly or posteriorly). The surgical approach, tumor size and RNS were identified as independent predictors of trifecta on multivariate analysis.

Conclusion RPRAPN is associated with superior perioperative outcomes in well-selected patients compared to TPRAPN. However, the data for the retroperitoneal approach were contributed by a few centers with greater experience with this technique, thus limiting the generalizability of the results of this study.

Keywords Retroperitoneal · RAPN · Partial nephrectomy · Propensity matching

Introduction

Incidental detection of renal masses has increased in recent times. Such incidentally detected renal masses are usually smaller in size and are of early stage [1]. Partial nephrectomy (PN) has become the standard of care for treating such incidentally detected small renal masses [2, 3]. Equivalent oncological and superior functional outcomes give an edge to PN over radical nephrectomy (RN) [2–4]. There has been a shift from open to minimally invasive PN due to perceived benefits of less pain, lower blood loss and shorter hospital stay [5, 6]. Robot-assisted partial nephrectomy (RAPN) has become the preferred minimally invasive modality due to its numerous advantages [6].

There is still a constant debate over the choice of surgical access, i.e., retroperitoneal or transperitoneal. Both the surgical accesses have their advantages and disadvantages. This debate is likely to persist in the absence of level I evidence. Surgeons' experience and tumor location are major factors

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Extended author information available on the last page of the article in deciding the access mode. Posteriorly located tumors may be more amenable for the retroperitoneal RAPN (RPRAPN) approach and anterior for transperitoneal RAPN (TPRAPN). However, this conjecture has been challenged by a study reporting similar outcomes for both the surgical approaches irrespective of tumor location [7]. Multiple studies have been reported in the past decade comparing the two surgical approaches [7–16]. A systematic review of these studies concluded that both the surgical approaches are equivalent in a well-selected patient population operated by experienced surgeons [17]. However, the level of evidence remains poor due to the absence of a well-conducted randomized controlled trial.

Vattikuti Collective Quality Initiative (VCQI) is a multicentric and multinational database with data collected from 18 centers across nine countries [8, 18, 19]. Thus, this database provides the best opportunity to examine the two surgical approaches in a multicentric setting in a diverse patient population. In a previous study using this database, Arora et al. compared 99 patients who underwent RPRAPN with 394 patients who underwent TPRAPN [8]. Multiple cases have been reported in the database during the last three years. Therefore, this study aimed to update the comparison between the two groups for perioperative outcomes. We also performed a propensity-matched analysis of the two groups for the possible factors that could impact trifecta outcomes. We also aimed to study the impact of tumor location (anterior/posterior) on outcomes following the two surgical approaches.

Materials and methods

Vattikuti collective quality initiative (VCQI) database

VCQI is a prospective web-based multi-institutional collaborative database for various robotic surgical procedures [8, 18, 19]. Database for RAPN is contributed by 18 participating institutions from 9 countries (USA, UK, India, Italy, Portugal, Belgium, Turkey, Australia and South Korea). The database is Health Insurance Portability and Accountability Act (HIPAA) compliant, and ethics clearance was obtained from each participating institution. From October 2014 to 2020, data of 3,801 patients who underwent RAPN were contributed from the participating centers. Due to the multi-institutional nature of the database, patients without adequate data had to be excluded from the study. After excluding patients with incomplete data, 2,550 patients were eligible for final analysis.

Demographic variables

For every patient, demographic variables such as age at the time of surgery, sex (male/female), and body mass index (BMI) were extracted. We also extracted data for clinical variables such as tumor size, estimated glomerular filtration rate (eGFR) using Modified diet in renal disease (MDRD) equation, symptoms (absent/local/systemic), polar location of the tumor (upper/middle/lower pole), number (single/multiple), laterality (unilateral/bilateral), solitary kidney and RENAL nephrometry score (RNS) [20].

Operative, postoperative and pathological factors

Data for operative factors such as surgical access (retroperitoneal/transperitoneal), operative time, warm ischemia time, blood loss, intraoperative blood transfusion, need for conversion to radical nephrectomy and intraoperative complications were also extracted. Complications were graded as per Clavien–Dindo classification [21].

Primary endpoint

The primary endpoint of this study was the comparison of trifecta outcomes between patients who underwent transperitoneal and retroperitoneal RAPN. Trifecta was defined as the absence of complications, negative surgical margins, and warm ischemia time less than 20 min or zero ischemia [18].

Statistical analysis

We checked the normality of continuous data using Kolmogorov–Smirnov and Shapiro tests of normality. An independent sample Student's t test was used if data were normally distributed. Kruskal–Wallis test was used for non-normally distributed variables. For categorical variables, Chi-square tests or Fisher's exact tests were used. Propensity scores were calculated for dependent variable surgical access (TPRAPN and RPRAPN) with independent variables of age, sex, side of the surgery, RNS, baseline eGFR and creatinine with trifecta as the primary outcome. Then 1:1 matching was performed without replacements for each patient based on propensity scores obtained with a caliper of 0.0001. All the statistical tests were two-sided and performed with a significance level of $p < 0.05$. All the statistical analyses were conducted using SPSS version 23 (IBM corporation, New York, USA) and Stata (version 16; StataCorp, College Station, TX, USA) [22].

Results

Baseline characteristics

Of the 2,550 patients included in this study, 326 (12.8%) underwent RPRAPN and 2,224 (87.2) underwent TPRAPN. Mean age of the patients included in this study was 57.6 years. There were 65.3% males and 34.7% females. Mean BMI, tumor size and CCI were 28.6 kg/m^2, 34.6 cm and 1.25, respectively. Most of the included patients were asymptomatic at presentation (84.2%). About 2.6% of the included patients has a single kidney. Preoperative hemoglobin, creatinine and eGFR were 13.8 gm/dL, 0.97 mg/dL and 80.5 ml/min, respectively. Most of the included tumors were of low (41.3%) or intermediate complexity (49.1%) as per RNS. Intraoperative complication, blood transfusion and conversion to radical nephrectomy were needed in 4.7%, 3.1% and 1.6% of the patients, respectively. Overall complications, positive surgical margins and trifecta outcomes were noted in 8.8%, 3% and 55.1% of the patients, respectively. Baseline comparison (prematching) of the two surgical approaches is provided in Table 1

Postmatching

There was statistically significant difference between the two groups for age, BMI, tumor size and preoperative eGFR before matching. After 1:1 matching, the two surgical groups matched well for age, sex, tumor side, tumor location, RNS, preoperative serum creatinine and eGFR (Table 2). Of the 326 patients who underwent RPRAPN, propensity matching in a 1:1 ratio was possible for 309 patients. Clinical tumor size and Charlson comorbidity index were significantly higher in the TPRAPN group (Table 2). At the same time, preoperative hemoglobin and BMI were significantly higher in the RPRAPN group. Compared to the TPRAPN group, tumors in the RPRAPN group were more likely to be posteriorly located (75.2% vs. 38.8%, $p=0.000$). Operative time and WIT were significantly shorter with RPRAPN. Intraoperative blood loss and need for blood transfusion were lower with RPRAPN. There were significantly higher intraoperative complications with RPRAPN (Table 3). However, there was no difference in the two groups for postoperative complications. Trifecta outcomes were significantly better with RPRAPN (70.2% vs. 53%, $p=0.000$) (Table 3).

Comparsion of outcomes with tumor location

We noted no significant change in overall results when comparing anterior tumors managed with TPRAPN and posterior tumors with RPRAPN (Supplementary table 1). Subgroup comparison of anterior and posterior tumors also revealed similar results (Supplementary tables 2 and 3).

Predictors of trifecta

We considered age, BMI, sex, RNS, surgical approach, tumor size, location, face of tumor and eGFR for prediction of trifecta in the matched patient cohort. The multivariate logistic regression analysis identified tumor size, RNS and surgical approach as independent predictors (Table 4).

Discussion

Partial nephrectomy has become a standard treatment option for managing patients with localized small renal masses [2]. Advances in surgical technique and equipment have allowed for satisfactory resection of many complex renal masses. With the dissemination of robotic technology and training programs across the globe, most of the partial nephrectomies are today performed robotically. Choice of surgical access in a given situation depends upon patient factors, tumor-related factors and surgeon experience [14]. The retroperitoneal approach allows direct access to the kidney without breaching the peritoneum, thereby reducing intestinal injury risk [14]. It also provides direct access to the renal artery and posteriorly located tumors without the need for flipping the kidney [14]. However, unfamiliar anatomy and limited working space are some of the limitations. Furthermore, due to the lack of proven benefit of one mode of access over another, choice in a given situation usually depends on surgeons' experience and familiarity with a particular space. This multicentric propensity-matched analysis of RPRAPN and TPRAPN provides the most extensive comparison of the two groups to the best of our knowledge.

We matched the two surgical groups for all the baseline factors that could influence the trifecta outcomes. We performed propensity matching for age, sex, side of the surgery, RNS, baseline eGFR and creatinine between the two groups. The two surgical groups were well matched for baseline characteristics except for BMI, clinical tumor size and CCI. BMI was significantly higher in the RPRAPN. Obesity could add to the surgical complexity, especially in the retroperitoneal route due to excessive fat deposition. However, we concede that the difference in BMI noted may be statistically significant but not clinically relevant (mean difference 1.4). Tumor size was significantly larger in the TPRAPN group. We did not consider this variable for propensity matching as it is known that RNS (that incorporates tumor size) is much more comprehensive in predicting the tumor complexity [20]. We did not

Table 1 Comparison of two surgical groups for the overall patient cohort

Variable	Overall (*n* = 2550)	Retroperitoneal (*n* = 326)	Transperitoneal (*n* = 2224)	*p*-value
Age (mean ± SD)	57.6 ± 12.9	60.3 ± 11.6	57.3 ± 13.1	**0.000**
Sex				
Male	1666(65.3%)	210 (64.4%)	1456 (65.4%)	0.710
Female	884(34.7%)	116(35.5%)	768(34.5%)	
BMI (Kg/m^2)	28.6 ± 6	29.7 ± 6	28.4 ± 6	**0.000**
Tumor size (mean ± SD) mm	34.6 ± 16.8	30.9 ± 14.1	35.1 ± 17.1	**0.000**
CCI (mean ± SD)	1.25 ± 1.4	1.3 ± 1.5	1.25 ± 1.46	0.535
Clinical symptoms				
Asymptomatic	2148(84.2%)	242 (74.2%)	1906 (85.7%)	
Local	371(14.5%)	75 (23%)	296(13.3%)	**0.000**
Systemic	31(1.2%)	9(2.76%)	22(0.9%)	
Single kidney	67(2.6%)	11 (3.3%)	56 (2.5%)	0.367
Tumor side				
Right	13.01(51%)	158 (48.4%)	1091 (49%)	0.842
Left	1249(49%)	168 (51.6%)	1133 (51%)	
Face of tumor				
Anterior	1392(54.6%)	65 (19.9%)	1327 (59.6%)	**0.000**
Posterior	1158(45.4%)	261 (80%)	897(40.4%)	
Polar location of tumor				
Upper	818(32.1%)	100 (30.6%)	718 (32.2%)	
Mid	951(37.3%)	130 (39.8%)	821 (36.9%)	0.586
Lower	781(30.6%)	96 (29.4%)	685 (30.8%)	
Preoperative hemoglobin (gm/dL)	13.8 ± 1.6	14.1 ± 1.6	13.7 ± 1.6	**0.000**
Preoperative creatinine (mg/dL)	0.97 ± 0.38	1.00 ± 0.28	0.97 ± 0.39	0.281
Preoperative eGFR	80.5 ± 24.1	76.3 ± 22	81.2 ± 24.4	**0.000**
Renal nephrometry score (Mean ± SD)	6.99 ± 1.84	7.05 ± 1.85	6.98 ± 1.84	0.543
RENAL complexity				
Low	1052(41.3%)	126 (38.6%)	926 (41.6%)	
Moderate	1252(49.1%)	168 (51.5%)	1084 (48.7%)	0.584
High	246(9.6%)	32 (9.8%)	214 (9.6%)	
Operative time	189.6 ± 66	163.4 ± 52.7	194.1 ± 67.1	**0.000**
Warm ischemia time	18.1 ± 11.4	16.1 ± 8.4	18.45 ± 11.7	**0.001**
Blood loss ml (Median with range)	100(10–9650)	50 (10–1600)	100 (10–9650)	**0.000**
Intraoperative transfusion	78(3.1%)	2 (0.6%)	76 (3.4%)	**0.006**
Intraoperative complication	121(4.7%)	39 (11.9%)	82 (3.6%)	**0.000**
Need for conversion to radical nephrectomy	40 (1.6%)	6(1.8%)	34 (1.52%)	0.671
Postoperative complications	224(8.8%)	21 (6.4%)	203 (9.1%)	0.754
Grade I	114(4.5%)	6 (1.8%)	108 (4.8%)	0.118
Grade II	53(2.1%)	8 (2.4%)	45 (2.0%)	
Grade III	43 (1.7%)	7 (2.1%)	36 (1.6%)	
Grade IV	14(0.6%)	0	14 (0.6%)	
Positive margin	76(3%)	8 (2.4%)	68 (3.05%)	0.550
Trifecta	1406(55.1%)	228 (69.9%)	1178 (52.9%)	**0.000**

SD standard deviation, *BMI* body mass index, *eGFR* estimated glomerular filtration rate, *CCI* Charlson comorbidity index

perform matching for the face of the tumor as this could theoretically favor one approach over another. However, Dell'Oglio et al. reported no advantage for TPRAPN for treating anterior tumors and RPRAPN for posterior tumors [7]. The authors reported equivalent outcomes for both surgical approaches irrespective of the tumor location [7]. Similarly, we did not find any change in overall results after adjusting tumor location for the surgical access. The

Table 2 Comparison of baseline characteristics between the two surgical groups

Variable	Transperitoneal ($n=309$)	Retroperitoneal ($n=309$)	*p*-value
Age (mean ± SD)	60.4 ± 10.6	59.9 ± 11	0.644
Sex			
Male	216 (69.9%)	205 (66.3%)	0.342
Female	93 (30.1%)	104 (33.6%)	
BMI (Kg/m^2)	28.5 ± 8.8	29.9 ± 6	**0.001**
Tumor size (mean ± SD) mm	35.8 ± 17.7	30.6 ± 14.1	**0.000**
CCI (mean ± SD)	1.6 ± 1.2	1.2 ± 1.5	**0.000**
Clinical symptoms			
Asymptomatic	271 (87.7%)	232 (75.1%)	
Local	34 (11%)	68 (22%)	**0.000**
Systemic	4 (1.3%)	9 (2.9%)	
Single kidney	10 (3.2%)	11 (3.5%)	0.824
Tumor side			
Right	159 (51.4%)	158 (51.1%)	0.936
Left	150 (48.6%)	151 (48.9%)	
Face of tumor			
Anterior	189 (61.1%)	62 (20.1%)	**0.000**
Posterior	120 (38.9%)	247 (79.9%)	
Polar location of tumor			
Upper	97 (31.4%)	97 (31.3%)	
Mid	112 (36.2%)	123 (39.8%)	0.561
Lower	100 (32.3%)	89 (28.8%)	
Preoperative hemoglobin (gm/dL)	13.7 ± 1.5	14.2 ± 1.6	**0.000**
Preoperative creatinine (mg/dL)	1.03 ± 0.47	1.0 ± 0.29	0.420
Preoperative eGFR	78 ± 23	76.7 ± 22	0.124
Renal nephrometry score (Mean ± SD)	7.06 ± 1.87	7.00 ± 1.8	0.786
RENAL complexity			
Low	120 (38.8%)	123 (39.8%)	
Moderate	156 (50.4%)	158 (51.1%)	0.795
High	33 (10.6%)	28 (9.06%)	
Number of lesions operated			
1	292 (94.4%)	287(92.8%)	
2	11 (3.55%)	16 (5.2%)	0.560
3	5 (1.6%)	6 (1.9%)	
6	1 (0.3%)	0	

SD standard deviation, *BMI* body mass index, *eGFR* estimated glomerular Filtration rate, *CCI* Charlson comorbidity index

findings of the present updated study are different from the previous VCQI database analysis [8]. This study noted RPRAPN associated with significantly shorter operative time and WIT. Intraoperative blood loss and the need for intraoperative transfusion were significantly higher in the TPRAPN group. Overall complications and positive surgical margins were similar in the two groups in the present study.

There was no difference in the two groups for operative time and WIT for the previous VCQI database study. In a multicentric matched analysis of 352 patients who underwent TPRAPN or RPRAPN by Harke et al [10], authors noted RPRAPN associated with significantly shorter operative time and WIT. Takagi et al. in a single-center study of RAPN for laterally located tumors noted comparable findings [15]. Two other multicenter propensity-matched studies have reported operative times favoring RPRAPN; however, WIT was similar in these two studies [11, 12]. The largest meta-analysis on the topic by Zhou et al. also reported shorter operative times with RPRAPN and comparable WIT [16].

Table 3 Comparison of perioperative outcomes following retroperitoneal and transperitoneal robot-assisted partial nephrectomy

Variable	Transperitoneal (*n* = 309)	Retroperitoneal (*n* = 309)	*p*-value
Operative time	191.1 ± 70.4	163.7 ± 54.1	**0.000**
Warm ischemia time	18.4 ± 10	16.1 ± 8.5	**0.002**
Blood loss ml (Median with range)	150 (10–9650)	50 (10–1600)	**0.000**
Intraoperative transfusion	10 (3.2%)	2 (0.6%)	**0.02**
Intraoperative complication	8 (2.6%)	37 (12%)	**0.000**
Conversion to open	0	0	
Gross violation of tumor bed	5	34	
Injury to abdominal organs	1	0	
Major bleeding from tumor vessel	2	2	
Unknown	0	1	
Need for conversion to radical nephrectomy	6(1.9%)	5 (1.6%)	0.671
Postoperative complications	23 (7.4%)	21 (6.8%)	0.754
Grade I	11 (3.5%)	6 (1.9%)	
Grade II	4 (1.3%)	8 (2.6%)	0.432
Grade III	7 (2.2%)	7 (2.2%)	
Grade IV	1 (0.3%)	0	
Positive margin	7	8	0.794
Trifecta	164 (53%)	217 (70.2%)	**0.000**

Table 4 Multivariate analysis to identify predictors of the trifecta

Trifecta	OR	Lower limit of CI	Upper limit of CI	p-value
Age	1.14	0.74	1.74	0.549
BMI	1.001	0.982	1.021	0.908
CCI	0.989	0.957	1.021	0.480
Clinical tumor size	0.974	0.960	0.988	**0.000**
eGFR	0.999	0.990	1.008	0.885
Tumor location				
Upper	0.831	0.504	1.370	0.467
Mid	0.776	0.470	1.281	0.322
Lower	Reference			
RNS	0.805	0.710	0.912	**0.001**
Tumor face				
Anterior	Reference			
Posterior	0.914	0.588	1.420	0.688
Access				
Retroperitoneal	Reference			
Transperitoneal	0.611	0.397	0.941	**0.025**

BMI body mass index, *eGFR* estimated glomerular filtration rate, *CI* confidence interval, *OR* Odds ratio, Charlson comorbidity index

Regarding blood loss, our findings are similar to previous studies by Takagi et al [15], Arora et al [8] and Mittakanti et al [11]. However, Paulucci et al [12] reported comparable blood loss in the two groups in their study. Data for intraoperative blood transfusion were not reported in any of these studies. Interestingly, we noted a significantly higher risk of intraoperative complications in patients undergoing RPRAPN. The most common complication was a gross violation of the tumor bed, and none of the patients required conversion to open in either group. Furthermore, the need for conversion to radical nephrectomy was similar in the two groups. In a multicentric study by Porpiglia et al. authors compared perioperative outcomes following transperitoneal or retroperitoneal minimally invasive PN [13]. In contrast to the present study, these authors reported higher intraoperative complications in the transperitoneal group. However, a significant proportion of the patients in this study had undergone laparoscopic surgery; therefore, results may not be comparable to ours.

These findings noted in the current research align with the results of previously published literature [7–13, 15, 17]. However, the trifecta outcomes were significantly higher in patients of the RPRAPN group. No impact on trifecta outcomes was noted even after controlling for the face of the tumor. Interestingly, the surgical approach remained an independent predictor of trifecta on multivariate analysis along with tumor size and RNS. This remains a novel finding of this study to the best of our knowledge. Literature on reporting consolidated outcomes such as trifecta or pentafecta following RPRAPN is limited. Carbonara et al. [9] in their study noted similar trifecta outcomes between the two groups. Similarly, Choi et al. [23] in their cohort of patients who underwent RPRAPN or TPRAPN, noted comparable pentafecta outcomes. However, the definition of trifecta or pentafecta outcomes used in these studies differs from ours.

Limitations

Despite being one of the largest series comparing RPRAPN and TPRAPN, this study has some limitations. Firstly, due to multicentric nature of database, surgical technique was not described in this study. Additionally, surgical skills and surgeon experience were variable. RPRAPN has been less preferred surgical technique with only 326 cases being reported from 18 centers over 6 years of time period. On exploratory analysis of our database, we noted that only a few centers had contributed to the data for RPRAPN to the VCQI database. Therefore, despite showing superior results, the use of this surgical technique is limited to those centers where surgeons are familiar with this technique. Secondly, there are certain limitations of the VCQI database related to lack of data on other treatment options, previous surgical history anesthesia and drain placement. Previous studies from the RAPN VCQI database have highlighted these limitations [8, 18, 19]. Thirdly, details of surgical technique such as tumor excision or enucleation are lacking in the database. Fourthly, another important limitation to consider is inequality of matched groups for BMI and tumor size. Tumor size is an important factor defining the complexity of renal masses. However, it is not the alone factor and RNS provides the more comprehensive data on tumor complexity. We did not consider BMI as a factor for matching as most of the previous studies have not reported BMI to be a predictor of trifecta outcomes following RAPN [24–27]. Lastly, due to the current study's retrospective nature, the possibility of selection bias cannot be eliminated.

Conclusion

This multicentric propensity-matched study showed that RPRAPN is associated with superior perioperative outcomes in well-selected patients compared to TPRAPN. Location of tumor (anteriorly or posteriorly) does not influence perioperative outcomes following RPRAPN. Surgical access (transperitoneal or retroperitoneal) is an independent predictor of the trifecta outcomes.

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Authors contribution All the authors were involved in data acquisition and manuscript editing. GS, MS, PA and GG were involved in conception, design, analysis, manuscript writing and editing. GG was involved in supervision of the project.

Declarations

Conflict of interest Ronney Abaza is a speaker for Intuitive Surgical, Conmed Inc and VTI. Benjamin J Challacombe, Kris K Maes, Rajesh Ahlawat and Gagan Gautam are proctors for Intuitive Surgical. Other authors report no conflict of interests.

Research involving human participants and/or animals This study is retrospective analysis of VCQI database, and ethics approval was obtained from all the participating centers prior to data collection.

Informed consent Need for consent waived off by ethics committee.

Data availability Corresponding author had full access to data and same can be provided on request to genuine authors.

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