Available online at www.sciencedirect.com

ScienceDirect

Journal of the Chinese Medical Association 81 (2018) 676–681

www.jcma-online.com

Original Article

The perioperative outcomes between renal hilar and non-hilar tumors following robotic-assisted partial nephrectomy (RAPN)

Shih-Yen Lu [a,c], Hsiao-Jen Chung [a,b,c,*], Eric Yi-Hsiu Huang [a,b,c], Tzu-Pin Lin [a,b,c], Alex T.L. Lin [a,b,c]

[a] *Department of Urology, Taipei Veterans General Hospital, Taipei, Taiwan, ROC*
[b] *Department of Urology, School of Medicine, National Yang-Ming University, Taipei, Taiwan, ROC*
[c] *Shu-Tien Urological Science Research Center, Taipei, Taiwan, ROC*

Received July 14, 2017; accepted November 2, 2017

Abstract

Background: The aim of this study was to compare the perioperative outcomes between renal hilar tumors and non-hilar tumors after robotic-assisted partial nephrectomy (RAPN).
Methods: A retrospective review of consecutive patients who underwent RAPN from December 2009 to September 2015 at our institution was recruited. Perioperative outcomes including demographic characteristics, perioperative, pathological and renal function outcomes were compared between the hilar group (n = 30) and non-hilar group (n = 170).
Results: In characteristics, hilar group was younger (52.4 vs. 58 years, $p = 0.04$) and had less body mass index (23.7 vs. 25.4 kg/m^2, $p = 0.018$). Hilar group had larger tumor size (4.8 vs. 3.7 cm, $p = 0.009$), higher Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) score (10.7 vs. 8.5, $p < 0.001$) and higher RENAL (radius, exophytic/endophytic properties of the tumor, nearness of tumor deepest portion to the collecting system or sinus, anterior/posterior description and the location relative to polar lines) score (9.0 vs. 7.4, $p < 0.001$). Hilar tumor was associated with longer operative time (293.6 vs. 240.5 min, $p = 0.001$) and warm ischemia time (39.9 vs. 21.8 min, $p < 0.001$). But there was no statistically difference in estimated blood loss (EBL), postoperative stay and complication rate. For pathological outcomes, there was no difference of positive margin rate and pathological T stage between these groups. For renal function outcomes, hilar tumor patients had no difference of the change of creatinine and estimated glomerular filtration rate (eGFR) at postoperative 6 and 12 month as compared with non-hilar tumor patients.
Conclusion: For renal hilar tumor, RAPN could provide acceptable results of perioperative, pathological and renal function outcome as compared with non-hilar tumor group. Thus RAPN is a safe and effective nephron-sparing surgery technique for renal hilar tumors.

Keywords: Kidney neoplasms; Nephrectomy; Robotics

1. Introduction

In the past decades, the incidental diagnosis of renal tumor has been increased significantly due to wide use of abdominal image modalities.[1] Since radical nephrectomy is an independent risk factor for patients developing newly chronic kidney disease,[2] partial nephrectomy (PN) has become the standard care in the treatment of renal tumor less than 4 cm and selected tumor up to 7 cm.[3] As compared laparoscopic PN (LPN) with

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

* Corresponding author. Dr. Hsiao-Jen Chung, Department of Urology, Taipei Veterans General Hospital, 201, Section 2, Shi-Pai Road, Taipei 112, Taiwan, ROC.
E-mail address: hjchung@vghtpe.gov.tw (H.-J. Chung).

https://doi.org/10.1016/j.jcma.2017.11.014

open PN, laparoscopic approach could provide comparable surgical, pathological and renal function outcomes.[4]

Renal hilar tumor was defined as a tumor located in the renal hilum, abutting the renal vessels, and/or renal pelvis seen on preoperative computerized tomography.[5,6] Due to more difficult to approach, laparoscopic partial nephrectomy need more surgical skills to achieve precise parenchyma resection and renal reconstruction.[6,7] Gill et al. showed the technical feasibility of laparoscopic PN for renal hilar tumor, but higher complication rate was still noted in hilar tumor even in experienced surgeon.[8] Previous literature had proved that RAPN had better operative outcomes as compared with laparoscopic PN.[9,10] Thus we hypothesized robotic approach could facilitate resection of these difficult lesions. The aim of this study was to analyze the perioperative outcomes between renal hilar tumor and non-hilar tumor following RAPN.

2. Methods

2.1. Data collection

We retrospectively reviewed charts of 204 consecutive patients who underwent RAPN from December 2009 to September 2015 at our institution. All operation was performed by three experienced robotic surgeons of our institution. Institutional review board approval was obtained before initiating the study.

All three surgeons agreed on hilar tumor definition that was consistent to literature, but these patients were separated into hilar and non-hilar tumor by one major surgeon. There were no specific exclusion criteria for RAPN in our institution. For hilar tumor cases, patients received RAPN if parenchymal reconstruction is technically feasible and safe unless clinically renal vein invasion (cT3 disease) which received radical nephrectomy alternatively. Three patients with bilateral renal tumors and one hilar tumor case who was converted to open radical nephrectomy due to grossly renal vein thrombus were excluded for analysis. Patients were classified as hilar (n = 30) or non-hilar (n = 170) tumor for analysis.

Patient demographic data collected included age, gender, body mass index (BMI), American Society of Anesthesiologists score (ASA score), and laterality. Maximal tumor size on preoperative image either CT or MRI scan, RENAL (radius, exophytic/endophytic properties of the tumor, nearness of tumor deepest portion to the collecting system or sinus, anterior/posterior description and location relative to the polar line) nephrometry score[11] (classified into low 4–6, intermediate 7–9, and high 10–12 complexity groups) and PADUA (Preoperative Aspects and Dimensions Used for an Anatomical) nephrometry score.[12]

The operative outcomes including operation time, warm ischemia time (WIT), renal hilar clamp rate, estimated blood loss (EBL), perioperative transfusion rate, collecting system repair rate, and post-operative hospital stay. Dindo-Clavian classification was used to categorize complications as minor (I ~ II) and major (III ~ IV) complications. Pathological reports including histology, malignancy rate, nuclear grade, lymphovascular invasion (LVI), margin status and pathological T stage were collected.

For functional outcome, creatinine level was collected at pre-operative, post-operative 3, 6 and 12 months. Estimated glomerular filtration rate (eGFR) were collected at the same time point and calculated according to the Modification of Diet in Renal Disease (MDRD) study equation.[13,14]

2.2. Surgical technique

In our institution, we do not routinely insert ureter catheter unless renal tumor was close or attach to ureter proved by preoperative image. We perform all RAPNs using a 5 ports transperitoneal approach with the patient in a 60° modified flank position depending tumor location. The surgical table is mildly flexed and positioned in a slight Trendelenburg position. The abdomen is insufflated to 12 mmHg via Veress needle at the lateral border of the rectus muscle and 2 cm above umbilicus level which later serves as a 12-mm camera port. Unlike previous RAPN technique,[15–17] we used three 8-mm ports for manipulation. These ports are placed at the lateral border of the rectus muscle below the costal margin, 3–5 cm cephalad to the inguinal ligament at ipsilateral lower quadrant abdomen and anterior axillary line at umbilicus level for monopolar curved scissor, Maryland bipolar forceps and ProGrasp forceps, respectively (Fig. 1). Port configuration can adjust according to tumor location to optimize working angle. The robot is positioned over the patient's back to have the camera oriented in line with the kidney.

For RAPN technique, the strategy is related to tumor characteristics and the kidney anatomy. Initial steps of the procedure including bowel mobilization, hilar identification and dissection to exposure renal vein and artery. We open Gerota's fascia in an area that is far away from the tumor to find the capsule. Peri-renal fat was dissected along the plane for adequately exposure the tumor and kidney mobilization. A laparoscopic ultrasound probe controlled by bedside assistance or a drop-in robotic ultrasound probe can be used by activating the Tilepro multi-input display. This intracorporeal ultrasound

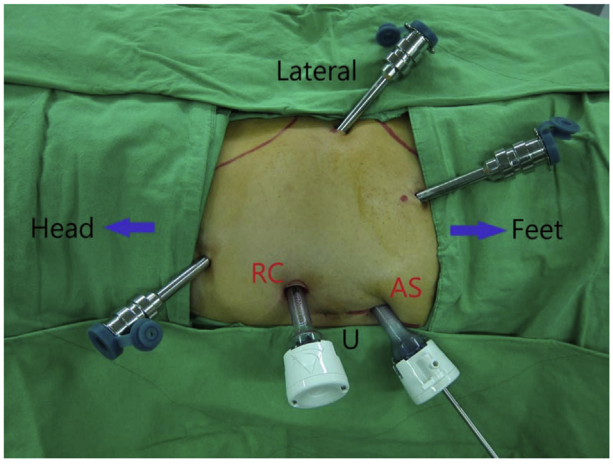

Fig. 1. Trocar placement for left RAPN. U: umbilicus; AS: assistance port; RC: robotic camera.

can help us accurately identify tumor location, depth and border, and then the renal capsule is scored to guide tumor resection with an adequate margin (Fig. 2). Before hilar control, 60 g Mannitol is given intravenously to aid in renal protection. We use bulldog clamps for hilar control, the renal artery is clamped first, and then the renal vein is selectively clamped. In selective cases, we performed unclamped technique. Once hilar clamped, the tumor was resected along previously scored margin with cold scissors. Bleeders and collecting system defect were closed with 3-o V-Loc continuous suture. Then cellulose bolster was placed at parenchyma defect and renorrhaphy is performed by interrupted 9-inch 1-O Vicryl suture with a knot and Hem-o-lok clip fixed to the free end. Floseal hemostatic matrix was leaved at parenchyma base then the Vicryl suture was tightened by two sliding Hem-o-lok clips.[18] Finally the Gerota's fascia was closed with 1-O Vicryl suture continuously. For renal hilar tumors, there was no specific tips or tricks. We followed the same surgery technique as standard steps from bowel mobilization, hilar dissection, tumor identification, tumor excision to renorrhaphy.

2.3. Statistical analysis

The statistical analysis was performed by using IBM SPSS ver. 20.0 (IBM Co., Armonk, NY, USA). Student T test, Pearson's chi-square test, Fisher's exact test and Mann–Whitney *U* test were used. The difference was considered statistically significant when p value less than 0.05.

3. Results

Table 1 showed the summarized demographic characteristics data. There was no significantly difference in ASA score, gender and laterality between hilar and non-hilar tumor group. But hilar tumor group were younger (52.4 vs. 58 years, $p = 0.04$) and had less BMI (23.7 vs. 25.4 kg/m^2, $p = 0.018$). Hilar tumor group had larger maximal image tumor size (4.8 vs. 3.7 cm, $p = 0.009$), also higher RENAL score (9.0 vs. 7.4, $p < 0.001$) and PADUA score (10.7 vs. 8.5, $p < 0.001$).

Table 1
Demographic characteristics.

Variables	Hilar tumor	Non-hilar tumor	p
No. of patients	30	170	
Mean ± SD			
Age, years	52.4 ± 15.3	58.0 ± 13.5	0.04[a]
BMI, kg/m^2	23.7 ± 3.3	25.4 ± 3.9	0.018[a]
ASA score	1.97 ± 0.55	2.02 ± 0.56	0.315[a]
Maximal tumor size, cm	4.8 ± 2.0	3.7 ± 1.8	0.009[a]
PADUA score	10.7 ± 1.1	8.5 ± 1.5	<0.001[a]
RENAL score	9.0 ± 1.2	7.4 ± 1.7	<0.001[a]
N (%)			
Male gender	14 (46.7)	99 (58.2)	0.239[b]
Right laterality	16 (53.3)	96 (56.5)	0.75[b]

ASA = American society of Anesthesiologists; BMI = body mass index; SD = standard deviation.
[a] Student T test.
[b] Pearson's Chi-square test.

For perioperative outcomes, the results were summarized in Table 2. Hilar tumor group had significantly longer operation time (293.6 vs. 240.5 min, $p = 0.001$) and warm ischemia time (39.9 vs. 21.8 min, $p < 0.001$). There was no significantly difference between the groups for EBL, perioperative blood transfusion rate, post-operative hospital stay and post-op complication rate either minor or major complication. There was no conversion to open method in this cohort study except one hilar tumor with renal vein thrombus witch was converted to open radical nephrectomy. For pathological outcomes, there

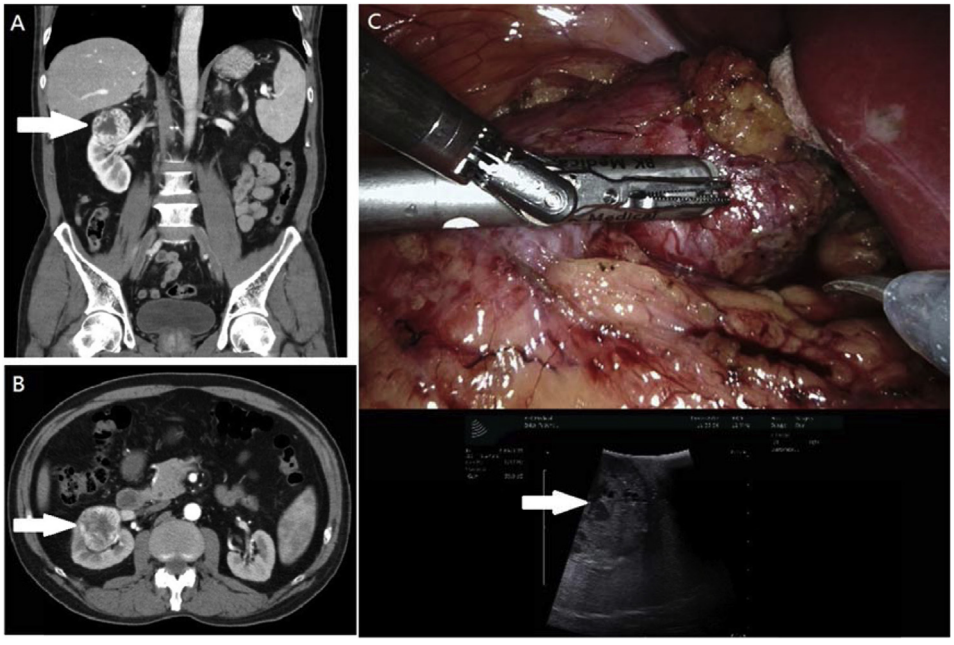

Fig. 2. A 69 year-old male patient with a 4.5 cm clear-cell type renal cell carcinoma at upper pole region of right kidney received RAPN without complication. (A) CT coronal view; (B) CT transverse view; (C) drop-in ultrasound with Tilepro multi-input display.

Table 2
Perioperative outcomes.

Variables	Hilar tumor	Non-hilar tumor	*p*
No. of patients	30	170	
Mean ± SD			
Operation time, min	293.6 ± 87.6	240.5 ± 80.1	0.001[a]
Warm ischemia time, min	39.9 ± 24.0	21.8 ± 16.0	<0.001[a]
Estimated blood loss, mL	418.7 ± 452.4	305.8 ± 336.9	0.285[a]
Post-op stay, day	6.0 ± 1.8	5.6 ± 1.7	0.259[a]
N (%)			
Zero-ischemia	3 (10)	27 (15.9)	0.581[b]
Peri-op transfusion	6 (20)	14 (8.2)	0.089[b]
Collecting system entry	18 (60)	68 (40)	0.041[c]
Post-op complications	7 (23.3)	25 (14.7)	0.278[b]
Grade I ~ II (minor)	7 (23.3)	21 (12.4)	
Grade III ~ IV (major)	0 (0)	4 (2.4)	
RCC	16 (53.3)	117 (68.8)	0.097[c]
LVI	2 (11.1)	5 (4)	0.217[b]
Positive margin	1 (5.3)	0 (0)	0.123[b]
Pathological stage			0.266[b]
pT1a	9 (56.2)	93 (75)	
pT1b	5 (31.2)	20 (16.1)	
pT2	0 (0)	1 (0.8)	
PT3a	2 (12.5)	10 (8.1)	

LVI = lymphovascular invasion; RCC = renal cell carcinoma.
[a] Mann–Whitney *U* test.
[b] Fisher's exact test.
[c] Pearson's Chi-square test.

was no significantly difference in malignancy rate, LVI, positive margin rate and pathological stage for malignant tumor between groups. There was one hilar tumor with positive margin who received subsequent laparoscopic radical nephrectomy.

The mean follow up duration was 28.0 vs. 32.3 months for hilar tumor and non-hilar tumor group, respectively. Table 3 showed the results of renal function outcomes. Hilar tumor group had no significantly difference of change of creatinine and eGFR at post-operative 6 and 12 months as compared with non-hilar tumor group.

4. Discussions

Renal hilar tumors need more surgical technique due to the proximity to hilar vessels and the complexity of renorrhaphy. With increasing experience, minimal invasive approach such as LPN and RAPN had become a more popular choice of nephron-sparing surgery for renal tumors. But LPN has steep learning curves and need more advanced surgical skills potentially limit its use especially for these renal hilar tumors.[4]

Table 3
Renal function follow up.

Variables	Hilar tumor	Non-hilar tumor	*p*
No. of patients	30	170	
Mean ± SD			
Cr., pre-op, mg/dl	0.81 ± 0.16	0.97 ± 0.52	0.054[a]
Change of Cr., post-op 6 M	0.03 ± 0.19	0.04 ± 0.21	0.59[a]
Change of Cr., post-op 12 M	0.04 ± 0.12	0.05 ± 0.19	0.913[a]
eGFR, pre-op, ml/min/1.73 m^2	94.1 ± 13.3	86.5 ± 25.3	0.161[a]
Change of eGFR, post-op 6 M	−8.2 ± 25.4	−7.4 ± 18.9	0.858[a]
Change of eGFR, post-op 12 M	−4.6 ± 15.9	−6.4 ± 14.4	0.977[a]

eGFR = estimated glomerular filtration rate.
[a] Mann–Whitney *U* test.

Previous literature had proved the feasibility of RAPN for renal hilar tumors. Rogers et al. reported the first series of RAPN for renal hilar tumors in 11 patients with a mean WIT of 28.9 min, mean EBL of 220 ml and mean hospital stay of 2.6 days.[6] Dulabon et al. conducted the largest series of multi-institute analysis comparing RAPN for hilar (n = 41) and non-hilar tumors (n = 405). Longer WIT (26.3 ± 7.4 min vs. 19.6 ± 10 min) was the major difference in the perioperative outcomes.[5]

Demographic characteristics data between hilar and non-hilar tumor groups were similar, except hilar tumor patients were younger and had less BMI while they had larger tumor size in this study. Larger tumor size in hilar tumor group at our cohort (4.8 vs. 3.7 cm, $p = 0.009$) was compatible with previous largest series analysis (3.2 vs. 2.6 cm, $p < 0.001$).[5] The reason why hilar tumors are larger was not clear, may be abundant blood supply from hilar vessels is the advantage to allowing them growth. Not surprisingly, these hilar tumors had higher RENAL score and PADUA score due to larger tumor size, endophytic properties and nearness of the collecting system. Centrality index (C-index) was another common method for renal tumor location measurement[19] and had comparable results for predicting peri-operative outcomes of LPN as compared with RENAL score.[20] But in our series, we did not use C-index to measure renal tumor location. Hilar tumor group was younger and had less BMI in our study, there was no previous literature showed the same finding. In our institute, partial nephrectomy could be done by robotic, laparoscopic or open approach depending on surgeon's preference. Previous literature demonstrated that partial nephrectomy via robotic approach could provide advantage such as shorter WIT than laparoscopic approach.[9,10] While comparing with open approach, RAPN showed the advantages of decreased estimated blood loss for endophytic tumor[21] and renal hilar tumors.[22] Thus for hilar tumors, RAPN will be a preference in this highly surgical skill dependent situation especially in young patients.

In our cohort, hilar tumor groups had larger tumor size, proximity to hilar vessels which need meticulous dissection; these could explain hilar tumor groups had longer operation time and WIT as compared with non-hilar tumor groups. This finding was compatible with Dulabon et al.[5] and Eyraud et al.,[7] hilar tumor group also had longer WIT (26.3 vs. 19.6 mins, $p < 0.001$, 27 vs. 17 mins. $p < 0.001$). Though our cohort study showed longer WIT (39.9 vs. 21.8 mins, $p < 0.001$) as compared with the largest series (3.5 vs. 2.9 cm), we have larger tumor size either hilar or non-hilar tumor (4.8 vs. 3.7 cm). Despite higher rate of collecting system entry in hilar group, there was no significant increase in overall complication rate. There was no post-operative urinoma which need double-J insertion in our series. For estimated blood loss, there was a trend of higher blood loss for hilar tumors but did not reach statistically difference either peri-operative blood transfusion rate. These findings were compatible with Dulabon et al. series.[5]

Our follow up protocol was the major difference to other series. In our institute, each patient had regularly post-op follow up at post-op 3, 6 and 12 months in the first year and mean follow up duration was 31.7 months. Eyraud et al.[7] compared eGFR for hilar and non-hilar tumor at post-operative day 3 and at last follow up which showed no significant difference between these groups. But their mean follow up duration was only 7.4 months. Other largest series conducted by Dulabon et al.[5] did not compared postoperative renal function outcomes. To our knowledge, this was the first study compared long-term renal function outcomes between hilar and non-hilar tumors following RAPN. Autorino et al.[23] compared RAPN for endophytic tumors with mesophytic and exophytic renal tumors, they showed the similar finding that endophytic tumors had longer WIT (21.7 vs. 20.2 vs. 17.1 mins, $p = 0.005$) though no significant difference of declined of eGFR (−9.4 vs. −11.7 vs. −6.5, $p = 0.215$) at latest follow up.

Renal function loss after PN could be explained as many reasons. Ischemia damage to preserved renal parenchyma is one of the major factors affecting post-operative renal function[24,25] and most study suggested WIT should be less than 25 min or 30 min at most to avoid renal function loss after PN.[24−26] Throughout longer WIT of hilar tumors, there are still much confounding factors affecting post-operative renal function. Recent literature raised a new concept suggest that the quality and quantity of preserved kidney are the primary factors to determine renal function after PN, with WIT playing a minor role.[27,28] Quality means pre-operative renal function and there was no significant difference of pre-operative creatinine and eGFR between two groups in cohort. Quantity means residual functioning parenchyma volume which could be estimated by % GFR preservation[26] or measured by mathematical model using volumetric CT.[28] These information were not available in our study, further nuclear study and volumetric CT scan may be addressed. Hilar tumor patients were younger than non-hilar tumor patients and this could be another confounding factor. Previous literature reported that patient age is one of the major factors affecting long-term renal function after PN.[29] Comorbidities causing deterioration of renal function should be considered as another factor but we do not have complete information in our study. Tumor composition did not showed significant difference between hilar and non-hilar tumors in our series (RCC: 53.3 vs 68.8%, $p = 0.097$) which may not be a confounding factors.

The present study has few limitations. First of all is our cohort is a retrospective study and the patients were electively received RAPN according to surgeon's preference. Secondly, we used the same definition for hilar tumors as previous literature[5,6] despite this is a subjective definition. And we did not considered intra-observer variability of this definition in our study. Furthermore, these RAPN cases were consecutively recruited for analysis, the learning curve bias may be another limitation.

In conclusion, our series conducted the longest follow up duration for hilar and non-hilar tumors following RAPN. The results showed comparable perioperative, pathological and renal function outcomes between these groups. Despite longer WIT of hilar tumors, renal function outcome showed no statistically difference till one year postoperatively. Thus for renal hilar tumors, robotic approach could facilitate resection of these difficult lesions during partial nephrectomy.

References

1. Znaor A, Lortet-Tieulent J, Laversanne M, Jemal A, Bray F. International variations and trends in renal cell carcinoma incidence and mortality. *Eur Urol* 2015;**67**:519−30.
2. Go AS, Chertow MD, Fan D, McCulloch CE, Hsu CY. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. *N Engl J Med* 2004;**351**:1296−305.
3. Leibovich BC, Blute M, Cheville JC, Lohse CM, Weaver AL, Zincke H. Nephron sparing surgery for appropriately selected renal cell carcinoma between 4 and 7 cm results in outcome similar to radical nephrectomy. *J Urol* 2004;**171**:1066−70.
4. Gill IS, Kavoussi LR, Lane BR, Blute ML, Babineau D, Colombo Jr JR, et al. Comparison of 1,800 laparoscopic and open partial nephrectomies for single renal tumors. *J Urol* 2007;**178**:41−6.
5. Dulabon LM, Kaouk JH, Haber GP, Berkman DS, Rogers CG, Petros F, et al. Multi-institutional analysis of robotic partial nephrectomy for hilar versus nonhilar lesions in 446 consecutive cases. *Eur Urol* 2011;**59**:325−30.
6. Rogers CG, Metwalli A, Blatt AM, Bratslavsky G, Menon M, Linehan WM, et al. Robotic partial nephrectomy for renal hilar tumors: a multi-institutional analysis. *J Urol* 2008;**180**:2353−6. Discussion 6.
7. Eyraud R, Long JA, Snow-Lisy D, Autorino R, Hillyer S, Klink J, et al. Robot-assisted partial nephrectomy for hilar tumors: perioperative outcomes. *Urology* 2013;**81**:1246−51.
8. Gill IS, Colombo Jr JR, Frank I, Moinzadeh A, Kaouk J, Desai M. Laparoscopic partial nephrectomy for hilar tumors. *J Urol* 2005;**174**:850−3. Discussion 3−4.
9. Aboumarzouk OM, Stein RJ, Eyraud R, Haber GP, Chlosta PL, Somani BK, et al. Robotic versus laparoscopic partial nephrectomy: a systematic review and meta-analysis. *Eur Urol* 2012;**62**:1023−33.
10. Benway BM, Bhayani SB, Rogers CG, Dulabon LM, Patel MN, Lipkin M, et al. Robot assisted partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: a multi-institutional analysis of perioperative outcomes. *J Urol* 2009;**182**:866−72.
11. Kutikov A, Uzzo RG. The r.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. *J Urol* 2009;**182**:844−53.
12. Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, De Caro R, et al. Preoperative aspects and dimensions used for an anatomical (padua) classification of renal tumours in patients who are candidates for nephron-sparing surgery. *Eur Urol* 2009;**56**:786−93.
13. Levey AS, Bosch JP, Lewis JB, Greene T, Rogers N, Roth D. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. *Ann Intern Med* 1999;**130**:461−70.
14. Levey AS, Coresh J, Balk E, Kausz AT, Levin A, Steffes MW, et al. National kidney foundation practice guidelines for chronic kidney disease: evaluation, classification, and stratification. *Ann Intern Med* 2003;**139**:137−47.
15. Benway BM, Bhayani SB, Rogers CG, Porter JR, Buffi NM, Figenshau RS, et al. Robot-assisted partial nephrectomy: an international experience. *Eur Urol* 2010;**57**:815−20.
16. Kaouk JH, Hillyer SP, Autorino R, Haber GP, Gao T, Altunrende F, et al. 252 robotic partial nephrectomies: evolving renorrhaphy technique and surgical outcomes at a single institution. *Urology* 2011;**78**:1338−44.
17. Kaouk JH, Khalifeh A, Hillyer S, Haber GP, Stein RJ, Autorino R. Robot-assisted laparoscopic partial nephrectomy: step-by-step contemporary technique and surgical outcomes at a single high-volume institution. *Eur Urol* 2012;**62**:553−61.
18. Benway BM, Wang AJ, Cabello JM, Bhayani SB. Robotic partial nephrectomy with sliding-clip renorrhaphy: technique and outcomes. *Eur Urol* 2009;**55**:592−9.

19. Simmons MN, Ching CB, Samplaski MK, Park CH, Gill IS. Kidney tumor location measurement using the C index method. *J Urol* 2010;**183**:1708−13.
20. Sugiura M, Suyama T, Kanesaka M, Fujimoto A, Hou K, Araki K, et al. Usefulness of R.E.N.A.L nephrometry scoring system and centrality index score for predicting outcome of laparoscopic partial nephrectomy. *J Laparoendosc Adv Surg Tech A* 2016;**26**:784−8.
21. Kara O, Maurice MJ, Malkoc E, Ramirez D, Nelson RJ, Caputo PA, et al. Comparison of robot-assisted and open partial nephrectomy for completely endophytic renal tumours: a single centre experience. *BJU Int* 2016;**118**:946−51.
22. Miyake H, Hinata N, Imai S, Furukawa J, Tanaka K, Fujisawa M. Partial nephrectomy for hilar tumors: comparison of conventional open and robot-assisted approaches. *Int J Clin Oncol* 2015;**20**:808−13.
23. Autorino R, Khalifeh A, Laydner H, Samarasekera D, Rizkala E, Eyraud R, et al. Robot-assisted partial nephrectomy (rapn) for completely endophytic renal masses: a single institution experience. *BJU Int* 2014;**113**:762−8.
24. Becker F, Poppel HV, Hakenberg OW, Stief C, Gill IS, Guazzoni G, et al. Assessing the impact of ischemia time during partial nephrectomy. *Eur Urol* 2009;**56**:625−35.
25. Thompsom RH, Lane BR, Lohse CM, Leibovich BC, Fergany A, Igor F, et al. Every minute counts when the renal hilum is clamped during partial nephrectomy. *Eur Urol* 2010;**58**:340−5.
26. Zargar H, Akca O, Autorino R, Brandao LF, Laydner H, Krishnan J, et al. Ipislateral renal function preservation after robotic-assisted partial nephrectomy (RAPN): an objective analysis using mercapto-acetyltriglycine (MAG3) renal scan data and volumetric assessment. *BJU Int* 2015;**115**:787−95.
27. Lane BR, Russo P, Uzzo RG, Hernandez AV, Boorjian SA, Thompsom RH, et al. Comparison of cold and warm ischemia during partial nephrectomy in 660 solitary kidneys reveals predominant role of nonmodifiable factors in determine ultimate renal function. *J Urol* 2011;**185**:421−7.
28. Mir MC, Campbell RA, Sharma N, Remer EM, Simmons MN, Li J, et al. Parenchymal volume preservation and ischemia during partial nephrectomy: functional and volumetric analysis. *Urology* 2013;**82**:263−8.
29. Fergany AF, Saad IR, Woo L, Novick AC. Open partial nephrectomy for tumors in a solitary kidney: experience with 400 cases. *J Urol* 2006;**175**:1630−3.