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Original article

The natural history of renal function after surgical management of renal cell carcinoma: Results from the Canadian Kidney Cancer Information System

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Abstract

Introduction and objective: Patients who undergo surgical management of renal cell carcinoma (RCC) are at risk for chronic kidney disease and its sequelae. This study describes the natural history of renal function after radical and partial nephrectomy and explores factors associated with postoperative decline in renal function.

Methods: This is a multi-institutional cohort study of patients in the Canadian Kidney Cancer Information System who underwent partial or radical nephrectomy for RCC. Estimated glomerular filtration rate (eGFR) and stage of chronic kidney disease were determined preoperatively and at 3, 12, and 24 months postoperatively. Linear regression was used to determine the association between postoperative eGFR and type of surgery (radical vs. partial), duration of ischemia, ischemia type (warm vs. cold), and tumor size.

Results and limitations: With a median follow-up of 26 months, 1,379 patients were identified from the Canadian Kidney Cancer Information System database including 665 and 714 who underwent partial and radical nephrectomy, respectively. Patients undergoing radical nephrectomy had a lower eGFR (mean = 19 ml/min/1.73 m^2 lower) at 3, 12, and 24 months postoperatively ($P < 0.001$). Decline in renal function occurred early and remained stable throughout follow-up. A lower preoperative eGFR and increasing age were also associated with a lower postoperative eGFR ($P < 0.01$). Ischemia type and duration were not predictive of postoperative decline in eGFR ($P > 0.05$). Severe renal failure (eGFR < 30 ml/min/1.73 m^2) developed postoperatively in 12.5% and 4.1% of radical and partial nephrectomy patients, respectively ($P < 0.001$).

Conclusions: After the initial postoperative decline, renal function remains stable in patients undergoing surgery for RCC. Patients undergoing radical nephrectomy have a greater long-term reduction in renal function compared with those undergoing partial nephrectomy.

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Ischemia duration and type are not predictive of postoperative renal function when adhering to generally short ischemia durations.

Keywords: Renal function; Partial nephrectomy; Radical nephrectomy; Renal failure; Renal cell carcinoma

1. Introduction

The standard of care for localized renal cell carcinoma (RCC) remains surgery with either partial or radical nephrectomy. Excellent cancer control is achievable, but the loss of nephrons can predispose patients to chronic renal failure and its sequelae.

Multiple small studies have addressed the association between type of surgery and renal functional outcomes. Partial nephrectomy results in a significantly lower risk of renal dysfunction than radical nephrectomy [1–4]. The role of ischemia duration and ischemia type (warm vs. cold) in the preservation of renal function in patients undergoing partial nephrectomy is not clear as available studies provide conflicting results [5–9]. Whether these surgical factors affect renal function in a modern cohort of patients with short ischemia durations remains understudied and unknown.

We have studied and report on the natural history of renal function after radical and partial nephrectomy in a Canadian multi-institutional cohort as well as the association between surgical factors and renal functional outcomes in patients undergoing partial nephrectomy.

2. Materials and methods

Patients were identified from the Canadian Kidney Cancer Information System (CKCis). CKCis is a multi-institutional database of patients with RCC and includes patients from 15 Canadian academic institutions. All patients who underwent either partial or radical nephrectomy were identified for potential study inclusion. Patients were included if they had both a preoperative measurement of serum creatinine within 6 months of surgery and at least 1 postoperative measurement >30 days postoperatively. Patients were excluded only if either of these estimated glomerular filtration rate (eGFR) measurements were unavailable. Data recorded included baseline demographics, presence of diabetes preoperatively, presence of hypertension preoperatively, type of surgery, tumor characteristics, and serum creatinine measurements both preoperatively and postoperatively. For patients undergoing partial nephrectomy, the ischemia type (cold vs. warm) and the ischemia duration were also collected when available.

eGFR was calculated at baseline (preoperatively) and at 1 to 5 months, 9 to 15 months, and 21 to 27 months postoperatively using the Chronic Kidney Disease Epidemiology Collaboration equation [10]. When multiple values were available for a patient, the values measured closest to surgery and to 3, 12, and 24 months postoperatively were chosen and are labeled as such in this study. The stage of chronic kidney disease (CKD) was determined both preoperatively and postoperatively according to the National Kidney Foundation staging system (Table 1) using the eGFR calculation closest to surgery and the lowest value postoperatively, excluding the first month [11]. Univariable and multivariable linear regression were used to compare the change in eGFR in patients undergoing partial or radical nephrectomy. The covariables in this multivariable model included age, sex, preoperative hypertension, preoperative diabetes mellitus, and baseline eGFR. Similarly, univariable and multivariable linear regression were used to determine the association between operative factors (ischemia type and duration) and postoperative eGFR in patients undergoing partial nephrectomy. The covariables in this model included age, sex, baseline eGFR, and tumor size.

3. Results

In total, 2,798 patients were identified in the CKCis database who underwent either partial or radical nephrectomy. Of these, 1,419 were excluded because of a lack of either preoperative or postoperative eGFR data, leaving 1,379 patients for inclusion who met the study criteria. The median follow-up was 26 months, and all included patients underwent surgery since 2008. Patients undergoing partial nephrectomy had significantly smaller tumors than those undergoing radical nephrectomy (median maximum diameter = 3.0 vs. 7.5 cm, respectively) and slightly higher baseline eGFR (83.7 vs. 76.8 ml/min/1.73 m^2). There were no differences in the proportion of patients with diabetes or hypertension in the partial or radical nephrectomy groups (P = 0.384 and 0.063, respectively). Table 2 shows baseline characteristics for all patients.

Patients undergoing radical nephrectomy had a significantly lower postoperative eGFR compared with those undergoing partial nephrectomy with an eGFR of 19.6, 19.9, and 19.6 ml/min/1.73 m^2 lower at 3, 12, and 24 months

Table 1
Stages of chronic kidney disease and corresponding GFR according to the National Kidney Foundation Staging System [11]

Stage	GFR
1	≥ 90
2	60–89
3	30–59
4	15–29
5	<15 Or dialysis

Table 2
Baseline characteristics stratified by type of surgery

	Total	Partial nephrectomy	Radical nephrectomy	P
N	1379	665 (48%)	714 (52%)	
Median age	61 (range: 21–91)	60 (21–91)	61 (27–87)	0.110
No. of male	910 (67%)	424 (64%)	486 (68%)	0.103
Diabetes	244 (18%)	111 (17%)	133 (19%)	0.384
Hypertension	690 (50%)	315 (47%)	375 (53%)	0.063
Median tumor size (cm)	4.5 (range: 0.5–24.0)	3.0 (0.5–16.0)	7.5 (1.0–24.0)	<0.001
Median follow-up (months)	26 (1–82)	26 (1–78)	26 (1–82)	0.592
Median baseline eGFR (ml/min/1.73 m^2)	80.6 (range: 5.9–192.0)	83.7 (8.5–248.0)	76.8 (5.9–121.0)	<0.001
Median ischemia duration (min)		23 (6–83)		

postoperatively, respectively. A lower preoperative eGFR, increasing age and larger tumor size were also associated with a lower postoperative eGFR when comparing the entire cohort. Hypertension and sex were associated with a decrease in postoperative eGFR at 24 months ($P < 0.001$ and 0.047, respectively), but not at 3 and 12 months ($P > 0.05$ for all). Diabetes was not associated with postoperative eGFR ($P > 0.05$ at all time intervals). Table 3 shows the multivariable linear regression for postoperative eGFR in partial and radical nephrectomy patients. The Fig. shows the change in eGFR according to type of surgery at 3, 12, and 24 months.

Among patients undergoing partial nephrectomy, 202 had warm ischemia and 230 had cold ischemia with the remainder of patients having no ischemia or unknown ischemia type. The median ischemia duration was 23 minutes (range: 6–83 min) and was 25 minutes for warm ischemia (range: 8–83 min) and 21 minutes (range: 6–50 min) for cold ischemia. Ischemia type was not associated with postoperative eGFR ($P > 0.05$ at all time intervals). Similarly, ischemia duration was not associated with postoperative eGFR ($P > 0.05$ at all time intervals). Again, increasing age and a lower preoperative eGFR were associated with a lower postoperative eGFR. Increasing tumor size was associated with lower postoperative renal function at 3 months ($P = 0.02$), but not at 12 and 24 months ($P = 0.35$ and 0.27). Sex, diabetes, and hypertension were not associated with postoperative eGFR in patients undergoing partial nephrectomy ($P > 0.05$ at all time intervals). Table 4 shows the multivariable linear regression model for postoperative eGFR in partial nephrectomy patients.

An increase in CKD stage occurred postoperatively in 821 (59.7%) patients, including 544 (76.1%) radical nephrectomy and 277 (41.7%) partial nephrectomy patients. Patients who had an increase in stage of CKD were more likely to be older, have lower baseline eGFR, and have undergone a radical nephrectomy ($P < 0.001$ for all). Progression to moderate CKD (stage 3, eGFR 30 to < 60 ml/min/1.73 m^2) occurred in 475 patients, including 359 (50.2%) and 116 (17.4%) undergoing radical and partial nephrectomy, respectively ($P < 0.001$). Progression to severe CKD (stage 4 or 5, eGFR < 30 ml/min/1.73 m^2) occurred in 117 (8.5%) patients, including 89 (12.5%) and 28 (4.2%) patients undergoing radical and partial nephrectomy, respectively ($P < 0.001$). Tables 5 and 6 show the preoperative and postoperative distribution of stages of CKD in radical and partial nephrectomy patients.

4. Discussion

The excellent oncological outcomes achieved with surgical management of organ confined RCC have shifted the focus of treatment to minimizing long-term morbidity. Specifically, the preservation of renal function has become of paramount

Table 3
Multivariable linear regression for postoperative eGFR in patients with partial and radical nephrectomy

	Linear regression for postoperative eGFR: regression coefficients		
	3 months	12 months	24 months
Intercept	35.8 (28.6, 42.8; $P < 0.001$	43.3 (34.9, 51.7; $P < 0.001$)	52.9 (42.6, 63.2; $P < 0.001$)
Extent (radical vs. partial nephrectomy	**−19.6 (−21.6, −17.6; $P < 0.001$)**	**−19.9 (−22.4, −17.5; $P < 0.001$)**	**−19.9 (−22.7, −17.1; $P < 0.001$)**
Baseline eGFR (ml/min/1.73 m^2)	**0.6 (0.6, 0.7; $P < 0.001$)**	**0.6 (0.5, 0.6; $P < 0.001$)**	**0.5 (0.5, 0.6; $P < 0.001$)**
Age (years)	**−0.2 (−0.3, −0.1; $P < 0.001$)**	**−0.3 (−0.4, −0.2; $P < 0.001$)**	**−0.4 (−0.5, −0.3; $P < 0.001$)**
Sex (male vs female)	0.6 (−1.2, 2.3; $P = 0.47$)	−1.8 (−3.8, 0.3; $P = 0.10$)	**−2.5 (−5.0, 0.1; $P = 0.047$)**
Diabetes	0.1 (−2.0, 2.1; $P = 0.97$)	−0.5 (−3.2, 2.1; $P = 0.68$)	−1.5 (−4.7, 1.7; $P = 0.36$)
Hypertension	−1.7 (−3.4, 0.1; $P = 0.06$)	−0.8 (−3.0, 1.3; $P = 0.44$)	−4.4 (−6.9, −1.8; $P < 0.001$)
Tumor size (cm)	**0.5 (0.2, 0.7; $P < 0.001$)**	**0.7 (0.4, 1.0; $P < 0.001$)**	**0.7 (0.3, 1.1; $P < 0.001$)**

The numbers are regression coefficients (95% CI) reflecting the predicted ml/min/1.73 m^2 change in eGFR per 1 unit increase in a continuous predictor or change in eGFR compared to the reference category of a binary predictor; 95% CI and P values in parenthesis.
Values in bold are significant at the 95% confidence interval.

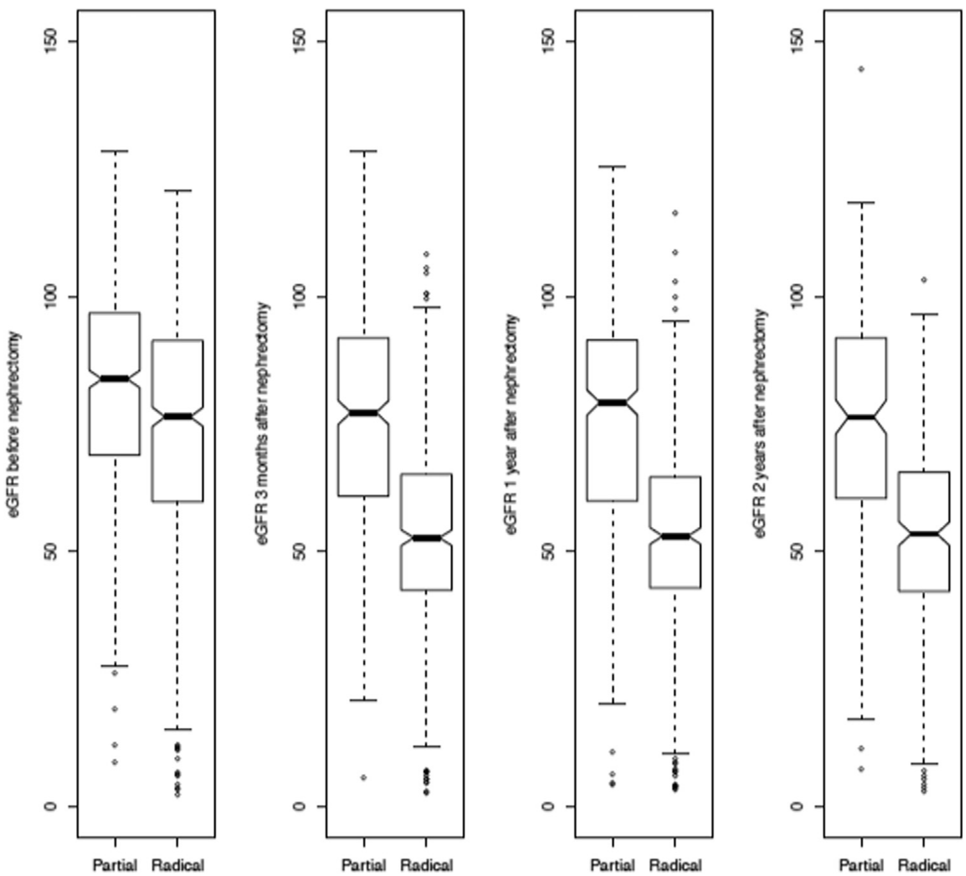

Fig. Boxplots for median eGFR and interquartile range (IQR) at baseline and 3, 12, and 24 months postoperatively.

concern. CKD is associated with several physiologic derangements including anemia, metabolic acidosis, electrolyte disturbances, and the need for renal replacement therapy. Furthermore, CKD is associated with an increased risk of cardiovascular events, hospitalization, and death [12].

Conceptually, partial nephrectomy should result in a greater preservation of renal function than radical nephrectomy. Several studies, including randomized trials, have confirmed this hypothesis [1–4]. For example, in a randomized trial by Scosyrev including 259 and 255 patients who underwent radical and partial nephrectomy, respectively, the incidence of moderate renal dysfunction (eGFR < 60) was significantly higher in the RN group (85.7% vs. 64.7%, $P < 0.001$) [1]. Our study provides further support for this finding with the median eGFR being nearly 20 ml/min/1.73 m^2 lower in those patients undergoing radical nephrectomy. Interestingly, the decline in renal function was similar at all postoperative time intervals,

Table 4
Multivariable linear regression model for postoperative eGFR in patients with partial nephrectomy

	Linear regression for postoperative eGFR: regression coefficients		
	3 months	12 months	24 months
Intercept	30.7 (17.0, 44.5; *P* < 0.001)	47.5 (26.7, 68.4; *P* < 0.001)	68.6 (47.7, 89.4; *P* < 0.001)
Baseline eGFR (ml/min/1.73 m^2)	**0.7 (0.6, 0.8; *P* < 0.001)**	**0.7 (0.5, 0.8; *P* < 0.001)**	**0.5 (0.4, 0.6; *P* < 0.001)**
Age (years)	**−0.2 (−0.3, 0; *P* = 0 .02)**	**−0.4 (−0.6, −0.2; *P* < 0.001)**	**−0.4 (−0.7, −0.2; *P* < 0.001)**
Sex (male vs. female)	2.2 (−0.5, 4.9; *P* = 0.10)	−0.7 (−4.9, 3.4; *P* = 0.72)	−1.5 (−6.4, 3.6; *P* = 0.54)
Diabetes	0.8 (−2.5, 4.2; *P* = 0.62)	0.9 (−5.5, 7.0; *P* = 0.76)	1.1 (−5.6, 7.8; *P* = 0.74)
Hypertension	−1.3 (−4.0, 1.5; *P* = 0.37)	2.4 (−2.1, 7.0; *P* = 0.30)	−3.6 (−8.6, 1.4; *P* = 0.16)
Ischemia duration (minutes)	0 (−0.1, 0.1; *P* = 0.73)	0 (−0.2, 0.2; *P* = 0.73)	0 (−0.2, 0.2; *P* = 0.89)
Ischemia type (warm vs. cold)	−1.4 (−4.4, 1.6; *P* = 0.36)	−1.9 (−6.5, 2.6; *P* = 0.41)	−0.9 (−6.5, 4.8; *P* = 0.77)
Tumor size (cm)	**−1.2 (−2.0, −0.3; *P* = 0.005)**	**−0.7 (−2.1, 0.6; *P* < 0.001)**	**−1.0 (−2.4, 0.5; *P* < 0.001)**

The numbers are regression coefficients (95% CI) reflecting the predicted ml/min/1.73 m^2 change in eGFR per 1 unit increase in a continuous predictor or change in eGFR compared to the reference category of a binary predictor; 95% CI and *P* values in parenthesis.
Values in bold are significant at the 95% confidence interval.

Table 5
Distribution of chronic kidney disease (CKD) stages both preoperatively and postoperatively for patients with radical nephrectomy

Preoperative CKD stage	Postoperative CKD stage					
	1	2	3	4	5	Total
1	4 (20.3)	90 (45.7)	102 (51.8)	1 (0.5)	0	197
2	3 (0.9)	47 (14.0)	257 (76.7)	18 (5.4)	10 (3.0)	335
3	0	4 (2.9)	75 (54.0)	47 (33.8)	13 (9.4)	139
4	0	0	2 (18.2)	3 (27.3)	6 (54.5)	11
5	0	0	0	0	12 (100)	12
Total	7	141	436	69	41	

Row percentages are reported in parenthesis indicating the proportion of patients in each stage of CKD postoperatively according to their preoperative stage of CKD.

indicating that the ultimate loss of renal function is likely determined at the time of nephron loss. This lends support to the idea that surgical renal failure has a different trajectory than medical renal failure with a lower propensity for progressive renal disease [13].

Renal cooling has long been thought to have a protective effect during operative renal ischemia and is often applied during open partial nephrectomy for challenging tumors. However, whether cold ischemia results in a clinically meaningful preservation of renal function during partial nephrectomy is unclear with available studies providing conflicting results [5–8]. In a nonrandomized study by Lane et al. including 300 and 360 patients who underwent partial nephrectomy with warm and cold ischemia, respectively, renal function outcomes were similar between the 2 groups. The median ischemia time was more than twice as long in the cold ischemia group (45 vs. 22 min), but the decline in renal function was the same (21% vs. 22%, $P = 0.7$). Conversely, Funahashi et al. looked at 123 patients who had warm or cold ischemia with similar ischemia durations between the 2 groups [6]. Patients who had warm ischemia were more likely to have sustained postoperative renal deterioration than those undergoing cold ischemia. In our study, we found no significant association between cold ischemia and preservation of renal function. The challenge in interpreting results from these nonrandomized studies is that patients who have cold ischemia often have more complicated tumors and require longer resection times than those who have warm ischemia. Until the results of adequately powered randomized controlled trials are known, continued use of cold ischemia with larger and more complex tumors seems prudent.

Traditional recommendations to keep ischemia times less than 30 minutes to minimize renal functional injury have been challenged by recent studies. Parekh et al. [9] looked at structural and functional renal changes in 40 patients undergoing partial nephrectomy, of which 82.5% had ischemia durations of >30 minutes. Ischemia duration was not correlated with postoperative renal function, and ischemia times of 30 to 60 minutes were tolerated with only mild structural changes. In our study, we similarly found no correlation between ischemia duration and postoperative changes in eGFR at all postoperative intervals. Our study had relatively short ischemia durations (median ischemia duration of 23 minutes) and this precludes generalizability of our results to longer ischemia durations. However, when adhering to relatively short ischemia times, it appears as though these modifiable surgical factors (ischemia type and duration) play only a minor role in preserving renal function.

Several other patient and surgical factors have been linked to postoperative change in renal function in patients undergoing partial nephrectomy. In a large retrospective study by Lane et al. including 1,169 patients undergoing partial nephrectomy, tumor size, age, preoperative eGFR, and male sex were associated with a greater decline in eGFR

Table 6
Distribution of chronic kidney disease (CKD) stages both preoperatively and postoperatively for patients with partial nephrectomy

Preoperative CKD stage	Postoperative CKD stage					
	1	2	3	4	5	Total
1	112 (42.1)	132 (49.1)	21 (7.8)	1 (0.4)	3 (1.1)	269
2	17 (8.6)	79 (40.1)	95 (48.2)	6 (3.0)	0	197
3	0	10 (10.7)	65 (69.9)	16 (17.2)	2 (2.2)	93
4	0	0	1 (25.0)	2 (50.0)	1 (25.0)	4
5	0	0	0	0	2 (100.0)	2
Total	129	221	182	25	8	

Row percentages are reported in parenthesis indicating the proportion of patients in each stage of CKD postoperatively according to their preoperative stage of CKD.

postoperatively [14]. There was also a weak association between warm ischemia duration and eGFR decline (-0.13 ml/min/1.73 m^2 for every minute of warm ischemia time). In our study, only increasing age and lower baseline eGFR were associated with postoperative eGFR. Interestingly, although size was weakly associated with postoperative renal function in partial nephrectomy patients at 3 months, there was no association at 12 and 24 months. This is in contrast to several studies in which the amount of renal parenchyma removed (i.e., tumor size) was associated with postoperative eGFR [5,8,15,16]. In our study population, there was a narrow spread of tumor sizes (interquartile range: 2.2–4 cm) and we hypothesize that with a larger range of tumor sizes a difference would be found.

We also report the stages of CKD preoperatively and postoperatively according to type of surgery. Not surprisingly, as stage of preoperative CKD increased, so did the proportion of patients progressing to higher stages of CKD after surgery. Stage for stage, the proportion of patients who progressed was generally less for partial nephrectomy patients as compared with radical nephrectomy patients. For example, 29.8% of patients undergoing radical nephrectomy with preoperative stage 2 CKD progressed to stage 5 CKD whereas a similar stage progression was not seen in any of the partial nephrectomy patients. Although direct comparisons between these 2 groups are not possible because of differences in patient and tumor characteristics, this nevertheless underscores the importance of nephron sparing surgery in patients with even mild impairments in renal function.

We recognize several limitations to this study. First, there were several patients in the database who were excluded from the study because of lack of eGFR data, introducing a potential selection bias. However, we assume that those with missing eGFR data are likely a random selection, and therefore, this bias is minimal. In addition, the patients undergoing radical nephrectomy had larger tumors than those undergoing partial nephrectomy. We feel that the overall finding that partial nephrectomy results in a significantly smaller decline in renal function remains valid. Finally, this study did not capture patient comorbidities, and therefore, there are multiple potential confounders unaccounted for. However, the strength of this study is the large number of included patients and the fact that it includes a general population of patients undergoing surgical management of RCC.

5. Conclusions

The most important determinants of renal function after surgical management of RCC are the type of surgery (partial vs. radical nephrectomy), preoperative renal function, and patient age. After the initial decline in renal function, patients with surgical renal failure appear to have a low propensity for progressive renal deterioration. In the modern era of partial nephrectomy with generally short ischemia times, ischemia type and duration do not appear to affect renal functional outcomes.

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References

[1] Scosyrev E, Messing EM, Sylvester R, Campbell S, Van Poppel H. Renal function after nephron-sparing surgery versus radical nephrectomy: results from EORTC Randomized Trial 30904. Eur Urol 2014;65:372–7, http://dx.doi.org/10.1016/j.eururo.2013.06.044.

[2] Krebs RK, Andreoni C, Ortiz V. Impact of radical and partial nephrectomy on renal function in patients with renal cancer. Urol Int 2014;92:449–54, http://dx.doi.org/10.1159/000355609.

[3] Zorn KC, Gong EM, Orvieto MA, Gofrit ON, Mikhail AA, Msezane LP, et al. Comparison of laparoscopic radical and partial nephrectomy: effects on long-term serum creatinine. Urology 2007;69:1035–40, http://dx.doi.org/10.1016/j.urology.2007.01.092.

[4] Clark ATD, Breau RH, Morash C, Fergusson D, Doucette S, Cagiannos I. Preservation of renal function following partial or radical nephrectomy using 24-hour creatinine clearance. Eur Urol 2008;54:143–9, http://dx.doi.org/10.1016/j.eururo.2008.03.037.

[5] Lane BR, Russo P, Uzzo RG, Hernandez AV, Boorjian SA, Thompson RH, et al. Comparison of cold and warm ischemia during partial nephrectomy in 660 solitary kidneys reveals predominant role of nonmodifiable factors in determining ultimate renal function. J Urol 2011;185:421–7, http://dx.doi.org/10.1016/j.juro.2010.09.131.

[6] Funahashi Y, Yoshino Y, Sassa N, Matsukawa Y, Takai S, Gotoh M. Comparison of warm and cold ischemia on renal function after partial nephrectomy. Urology 2014;84:1408–12, http://dx.doi.org/10.1016/j.urology.2014.08.040.

[7] Abdeldaeim HM, Abou Youssif TM, Abdel Wahab MM, Kotb AF, El Gebaly OF, Mokhless IA. Prospective randomized comparison between cold and warm ischemia in patients with renal insufficiency undergoing partial nephrectomy. Urology 2015;85:862–8, http://dx.doi.org/10.1016/j.urology.2014.11.046.

[8] 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, http://dx.doi.org/10.1016/j.urology.2013.03.068.

[9] Parekh DJ, Weinberg JM, Ercole B, Torkko KC, Hilton W, Bennett M, et al. Tolerance of the human kidney to isolated controlled ischemia. J Am Soc Nephrol 2013;24:506–17, http://dx.doi.org/10.1681/ASN.2012080786.

[10] Levey AS, Stevens LA, Schmid CH, Zhang YL, Castro AF, Feldman HI, et al. A new equation to estimate glomerular filtration rate. Ann Intern Med 2009;150:604–12.

[11] National Kidney Foundation. KDOQI Chronic Kidney Disease Guidelines 2002. Available at: http://www2.kidney.org/professionals/KDOQI/guidelines_ckd/toc.htm [accessed 5.08.15.].

[12] Go AS, Chertow GM, Fan D, McCulloch CE, Hsu C. Chronic kidney disease and the risks of death, cardiovascular events, and hospitalization. N Engl J Med 2004;351:1296–305, http://dx.doi.org/10.1056/NEJMoa041031.

[13] Lane BR, Demirjian S, Derweesh IH, Takagi T, Zhang Z, Velet L, et al. Survival and functional stability in chronic kidney disease due to surgical removal of nephrons: importance of the new baseline glomerular filtration rate. Eur Urol 2015;68:996–1003, http://dx.doi.org/10.1016/j.eururo.2015.04.043.

[14] Lane BR, Babineau DC, Poggio ED, Weight CJ, Larson BT, Gill IS, et al. Factors predicting renal functional outcome after partial nephrectomy. J Urol 2008;180:2363–8, http://dx.doi.org/10.1016/j.juro.2008.08.036.

[15] Simmons MN, Fergany AF, Campbell SC. Effect of parenchymal volume preservation on kidney function after partial nephrectomy. J Urol 2011;186:405–10, http://dx.doi.org/10.1016/j.juro.2011.03.154.

[16] Chan AA, Wood CG, Caicedo J, Munsell MF, Matin SF. Predictors of unilateral renal function after open and laparoscopic partial nephrectomy. Urology 2010;75:295–302, http://dx.doi.org/10.1016/j.urology.2009.09.027.