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Mini Review

Preoperative Evaluation of the Renal Function Before Kidney Cancer Surgery

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Abstract

Renal function is the basic focus of examination before kidney cancer surgery and determines the choice of surgery procedure. The prediction of renal function after surgery may also affect the surgical method, and it will certainly affect the prognosis of the patient. Herein, we provide a review of the relevant literature on partial nephrectomy (PN) and radical nephrectomy (RN) respectively, discuss methods for estimating kidney function, and compare effects. We found that the most reliable way to predict new baseline glomerular filtration rate (GFR) after PN was the quantitative estimation of the Percent of Preserved Parenchymal Mass (PPPM), while the simplest way to predict new-baseline GFR after RN was derivation from contralateral kidney, with ≥45 mL/min/1.73 m^2 considered a good cutoff to evaluate the kidney function and survival outcomes. In addition, based on AI, the imaging-guided analysis would provide a feasible, simple, and reliable prediction model.

Introduction

In renal cancer surgery, kidney function is one of the most fundamental topics during preoperative counseling. When it is technically feasible, partial nephrectomy (PN) is recommended for clinical T1 renal tumors for its oncologic equivalence to radical nephrectomy (RN), while radical nephrectomy is essential when there could be one of several consequences, for example, carcinoma of kidney pelvis and complex renal tumor with normal contralateral kidney.[1,2] In this clinical dilemma, effective kidney function prediction is of significant importance.

In several large-population studies, kidney function was reported to be associated with non-cancer mortality and cancer-specific survival. In their meta-analysis, Simon *et al*. (2012) suggested that partial nephrectomy conferred a lower risk of chronic kidney disease (HR 0.39, $p < .001$) and a survival advantage (HR 0.81, $p < 0.001$).[3] Antonelli and his colleagues also demonstrated that cancer-specific mortality was associated with estimated glomerular filtration rates (eGFR) when they were below the cutoffs, and renal function should be preserved to improve cancer-related survival.[4] On the other hand, some recent investigations revealed that kidney function was not associated with cancer-specific mortality. Moreover, Gershman *et al*. (2018) revealed that radical nephrectomy was associated with an increased risk of chronic kidney disease but not with cancer-specific mortality or all-cause mortality.[5] And in the unique prospective research (EORTC 30904), PN achieved better kidney function and was not associated with better survival outcomes.[6,7] Campbell and his team found that patients with a new baseline glomerular filtration rate (NBGFR) ≥45 mL/minute/1.73 m^2 had a better survival outcome and an increased NBGFR above this cutoff was not correlated with a better survival outcome.[8] Furthermore, their recent research confirmed that kidney function was not associated with cancer-specific survival, and an increased preoperative eGFR was associated with reduced all-cause mortality.[9]

However, the significance of kidney function for survival is still in debate but whatever the outcome, effective kidney function prediction remains important during clinical management of kidney tumors. If a higher GFR is required, PN should be performed if feasible. If the contralateral kidney had enough GFR, PN or RN would not be a difficult decision for a complicated renal mass. In this review, we will analyze the most popular methods of kidney function prediction and compare their effects. In PN cases, parenchymal volume preservation is the most important part of renal function preservation, while in RN cases, the compensation of the contralateral kidney is critical to new-baseline kidney function. Thus, we divided the review into two parts; the first one is focused on PN and the other on RN.

Keywords: Renal function; Partial nephrectomy (PN); Radical nephrectomy (RN); Glomerular filtration rate (GFR).

Abbreviations: AI, artificial intelligence; C-index, centrality index; CSA, contact surface area; DAP, diameter-axial-polar; GFR, glomerular filtration rate; NBGFR, new baseline glomerular filtration rate; PADUA, preoperative aspects and dimensions used for an anatomical classification; PN, partial nephrectomy; PPPM, percent of preserved parenchymal mass; QE, quantitative estimation; RN, radical nephrectomy.

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Table 1. Several predicting models based on regression analysis

Research	No.	Endpoints	Results	Variables
Shum *et al*, 2017[18]	461	eGFRs	Coefficients of determination: 0.70	age, race, sex, BMI, diabetes, HTN, IHD, stroke; preop. creatinine, preop. ipsilateral KV, SK; size
Bhindi *et al*, 2019[19]	1920	eGFRs	Marginal R^2: 0.62	age, DB, HTN preop. eGFR, PNU, SK
Martini *et al*, 2018[20]	999	25% eGFR decrease	C index: 0.75	age, CCI, sex, preop eGFR RENAL score
Bertolo *et al*, 2019[21]	1897	NB-CKD stage	AUC: 0.79	age, sex, BMI, preop. CKD stage; RENAL score
Mari *et al*, 2022[22]	981	25% eGFR decrease	AUC: 0.82	age, sex, DB, CCI, peripheral vascular disease, preop. eGFR, PADUA score

AUC, area under curve; BMI, body mass index; CCI, charlson comorbidity index; C-index, centrality index; DB, diabetes; eGFR, estimated glomerular filtration rate; HTN, hypertension; IHD, ischemic heart disease; KV, kidney volume; NB-CKD, new baseline chronic kidney disease; PADUA, preoperative aspects and dimensions used for an anatomical classification; PNU, proteinuria; preop., preoperative; SK, solitary kidney.

Kidney function prediction for patients undergoing PN

In PN cases, if the ischemia time is limited (less than 30 min), parenchymal volume preservation is at the center of kidney function prediction. Until now, the Percent of Preserved Parenchymal Mass (PPPM) has been the most reliable and reasonable method of predicting new-baseline kidney function. However, once AI based on a 3D reconstruction system can calculate the volume of parenchymal loss, it will provide a feasible, simple, and objective method and Dr. Campbell from Cleveland Clinic has already presented his initial work on this topic.[10] If the ischemia time is extended, kidney function recovery must be taken into consideration. As reported, every minute above 30 min would affect recovery from ischemia.[11] The compensation of the contralateral kidney has proven limited and not significant. A new method combining PPPM and an extended ischemia time should be developed and evaluated for efficacy above that of PPPM alone. Based on parenchymal volume preservation, several methods have been developed to predict postoperative kidney function or new-baseline kidney function.

It has been reported that PPPM is strongly associated with postoperative kidney function.[12] Surgeon assessment of volume preservation before PN (subjective estimation of PPPM) and calculating parenchymal volume based on imaging (quantitative estimation PPPM) are reasonable estimates of functional renal volume preservation. Also, nephrometry scores such as RENAL—(R)adius, (E)xophytic/endophytic, (N)earness to collecting system/sinus, (A)nterior/posterior, and (L)ocation relative to polar lines—nephrometry, preoperative aspects and dimensions used for an anatomical classification (PADUA), centrality index (C-index), diameter-axial-polar (DAP), and contact surface area (CSA), which are scoring systems designed to quantify tumor complexity, are reported to be associated with kidney function preservation.[13–17] As listed in Table S1, most scoring systems were modestly correlated with ipsilateral kidney function and only the DAP score had a favorable correlation to postoperative kidney function, but it was not validated in another cohort. Even for quantitative estimation (QE) PPPM, the correlation with ipsilateral kidney function was significant and modest ($r = 0.46$) although the correlation between QE PPPM and postoperative global renal function was strong ($r=0.91$).[12] These results might reveal that the minor variation of ipsilateral kidney function had a limited impact on the total kidney function of patients with normal contralateral kidneys.

Besides the above methods, some prediction models have been developed based on regression analysis to predict new-baseline kidney function (listed in Table 1).[18–22] In 2019, Mayo Clinic developed a new model to predict kidney function for patients undergoing renal surgery.[23] For PN cases, age, solitary kidney, hypertension, preoperative eGFR, preoperative proteinuria, and surgical approach were associated with worse long-term renal function. The marginal and conditional R^2 GLMM values of this model in predicting long-term renal function were 0.62 and 0.85. An external validation from Belgium demonstrated that early postoperative renal failure following PN and RN showed an AUC of 0.816 and 0.825 using the Mayo model and developed a new model to predict long-term renal function; the marginal and conditional R^2 GLMM values were 0.591 and 0.855 for the PN cases, and 0.363 and 0.849 for the RN cases, respectively.[24] However, both of these models were similar and suffered from being too complicated to perform in clinical practice. Aguilar Palacios D *et al*. from Cleveland Clinic also developed a simple model to predict new-baseline renal function. The accuracy of predicting renal function was 83% and 82% in internal and external validation. The AUC values to differentiate whether new-baseline renal function ≥45 mL/minute/1.73 m^2 were 0.89 and 0.91 in internal and external validation.[25] As we know, the new-baseline renal function ≥45 mL/minute/1.73 m^2 was a critical cutoff in evaluating whether the renal function would affect overall survival and the prediction model seemed strong in evaluating perioperative kidney function.

Kidney function prediction for patients undergoing RN

Different from PN cases, all parenchymal masses in the ipsilateral kidney were removed with tumor. The prediction of new-baseline kidney function focused on the compensation of the contralateral kidney. In addition, some methods have been developed based on regression analysis to predict new-baseline kidney function.

Both Mayo Clinic and Cleveland Clinic have developed models to predict renal function after radical nephrectomy. In the Mayo Clinic's model, older age, diabetes, lower preoperative eGFR, worse preoperative proteinuria, and smaller tumor size were associated with worse new-baseline renal function. The calculation method, however, is somewhat complicated.[23] Moreover, they found that time from surgery interacted with a number of factors, which meant some comorbidity could affect kidney function in long-term follow-up and may not be derived from renal surgery.

In Cleveland Clinic's model, the method of prediction of new-baseline renal function is simple. Based on split renal function from parenchymal volume analysis, the model focuses on the compensation of the contralateral kidney, which would be simple and consistent. They found that age (−0.85, $p < 0.01$), global preoperative estimated glomerular filtration rate (−0.28, $p < 0.01$), and split renal function of the removed kidney (0.61, $p < 0.01$) were

Table 2. Kidney function prediction for patients underwent PN or RN

Surgical procedure	Theoretical bases	Predictive methods
PN	Ischemia time less than 30 min	The volume of parenchymal loss calculated by AI
	Ischemia time more than 30 min	Subjective estimation of PPPM and quantitative estimation of PPPM
		RENAL, PADUA, C-index, DAP, CSA
		Mayo model
		Belgium model
		Cleveland model
RN	Compensation of contralateral kidney	Mayo model
		Cleveland model

AI, artificial intelligence; C-index, centrality index; CSA, contact surface area; PADUA, preoperative aspects and dimensions used for an anatomical classification; PN, partial nephrectomy; PPPM, percent of preserved parenchymal mass; RN, radical nephrectomy.

independent predictors of renal function compensation. Based on these findings, they developed an equation to calculate the NB-GFR: 35 + preoperative glomerular filtration rate (× 0.65) − 18 − age (× 0.25) + 3 (if tumor size >7 cm) − 2 (if diabetes).[26] They then developed a new simple method of predicting new baseline eGFR: 1.24 × preoperative eGFR of the contralateral kidney. They compared this simple method with five other models that were not based on split renal function. The results revealed that the new equation based on split renal function and compensation offered a better prediction than the five other models, including their own models and those of Mayo.[27,28]

The compensation of the contralateral kidney in RN cases was associated with the primary renal function of each kidney and comorbidity, which was critical to recovery from ischemia and long-term postoperative kidney function in PN cases. The renal function of each kidney was easy to estimate, while the degree of each related comorbidity was difficult to calculate making it difficult to build a feasible and reliable model. Thus, a multicenter, large-populated prospective clinical trial should be performed to collect detailed comorbidity data and evaluate its effect on compensation and recovery from ischemia and long-term kidney function (Table 2).

Prospective

Until now, the simplest method of predicting new-baseline GFR after RN was derivation from the contralateral kidney, and the most reliable method after PN was a quantitative estimation of PPPM. In addition, some measures have also been reported as predictors of postoperative renal function, such as preoperative MR volumetry and perioperative blood transfusion.[29,30] These metrics, although valid, have yet to be tested in terms of reliability in clinical use. At present, 3D reconstruction systems and AI are being widely applied in this field. We believe that with the help of different forecasting models, 3D reconstruction systems, and AI calculation, prediction will become quicker, more consistent, and simpler in the hopefully not-too-distant future.

Conclusions

To build a favorable model of predicting renal function was not simple. In some models, preoperative factors and postoperative factors were mixed, and the prediction value was confusing.[31] In the meantime, the primary endpoint was also important for model building. In the early period, most research focused on calculating an exact value for kidney function, which was a continuous variable, and increased the complexity of prediction. In recent years, we have found that greater than 45 mL/minute/1.73 m^2 is a good cutoff to evaluate kidney function and survival outcomes; calculating whether kidney function is >45 mL/minute/1.73 m^2 seems a much better method. Moreover, based on AI, imaging-guided analysis would make a feasible, simple, and reliable prediction model.

Supporting information

Supplementary material for this article is available at https://doi.org/10.14218/CSP.2023.00025.

Table S1. The renal function predicting values based on scoring systems of tumor complexity.

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Conflict of interest

One of the authors, Dr. Yun-Lin Ye has been an editorial board member of *Cancer Screening and Prevention* since March 2022. The authors have no other conflict of interests.

Author contributions

Contributed to study concept and design (TNC and YLY), acquisition of the data (JLL and YLY), assay performance and data analysis (TNC, JLL, ZKQ, and YLY), drafting of the manuscript (TNC and YLY), critical revision of the manuscript (YLY and ZKQ), supervision (YLY and ZKQ).

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