Estimation and Prediction of Renal Function in Patients With Renal Tumor

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Purpose: The goals of surgery for renal tumors include the preservation of renal function. When considering surgical options, it is important to accurately assess renal function and the risk of postoperative chronic kidney disease.

Materials and Methods: An institutional database was used to identify 359 patients who underwent nephrectomy or partial nephrectomy. Creatinine clearance was estimated using 14 previously published models and compared with creatinine clearance measured using a 24-hour urine collection. Models were generated for predicting renal function following nephrectomy or partial nephrectomy. All models were validated with an external data set of 245 patients.

Results: Models that accurately estimated creatinine clearance preoperatively and postoperatively were the Cockcroft-Gault model based on actual weight, and the Mawer, Björnsson, Hull and Martin models. In patients with an estimated creatinine clearance between 60 and 89 ml per minute preoperatively the risk of chronic kidney disease (creatinine clearance less than 60 ml per minute) after nephrectomy and partial nephrectomy was 58% and 15%, respectively (p <0.001). In patients undergoing nephrectomy age and weight were independent predictors of decreased creatinine clearance. A predictive model based on age and weight was highly accurate when applied to an external population (R = 0.757). A model for predicting renal function after partial nephrectomy based on age and tumor size was highly accurate in the external population (R = 0.848). A Web based tool was developed to estimate current and predict postoperative creatinine clearance (http://www.roswellpark.org/Patient_Care/Specialized_Services/Renal_Function_Estimator).

Conclusions: The Cockcroft-Gault model based on actual weight is 1 of 5 models that accurately estimates renal function in patients with a kidney tumor. Models were developed and externally validated to predict renal function following nephrectomy.

Key Words: kidney, kidney neoplasms, creatinine, nephrectomy, logistic models

Radical nephrectomy has long been considered the standard treatment for renal tumors. Following nephrectomy end stage renal disease requiring chronic dialysis is rare. However, maximal preservation of renal function is an important goal of surgery.1 Partial nephrectomy is a nephron sparing treatment for renal tumors that minimizes the risk of CKD but partial nephrectomy may be underused.2
Several studies have documented the morbidity associated with CKD. Go et al reported a graded association between a decreased GFR and the risk of adverse medical events in a community based population of more than 1 million adults. The risks of death, cardiovascular event and hospitalization were significantly increased even in patients with only a minimal compromise in renal function, ie a GFR of 45 to 59 ml per minute. Mathew et al performed a meta-analysis of 31 studies to look at postoperative outcomes in patients with kidney disease and found that CKD was an independent risk factor for death and cardiovascular morbidity after noncardiac surgery.

Previous studies in patients with renal tumors have used Scr to assess renal function. However, the relationship between Scr and renal function is not linear and patients with normal Scr can have CKD. A large number of predictive models have been developed to more accurately estimate renal function (see Appendix). However, to our knowledge none of these models have been validated for use in patients with renal tumors. Therefore, we compared the accuracy of 14 previously described models for

### Table 1. Patient characteristics

<table>
<thead>
<tr>
<th></th>
<th>Training Set</th>
<th>Validation Set</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. pts</td>
<td>359</td>
<td>245</td>
</tr>
<tr>
<td>Mean age (range)</td>
<td>62 (28–92)</td>
<td>62 (23–85)</td>
</tr>
<tr>
<td>Mean kg/m² body mass index (range)</td>
<td>31 (16–58)</td>
<td>29 (15–67)</td>
</tr>
<tr>
<td>No. female (%)</td>
<td>126 (35)</td>
<td>113 (46)</td>
</tr>
<tr>
<td>No. black (%)</td>
<td>26 (7)</td>
<td>71 (29)</td>
</tr>
<tr>
<td>No. nephrectomy (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>250 (70)</td>
<td>138 (56)</td>
</tr>
<tr>
<td>Partial</td>
<td>109 (30)</td>
<td>107 (44)</td>
</tr>
<tr>
<td>Mean cm tumor size (range)</td>
<td>5.6 (0.6–23)</td>
<td>4.9 (9.8–19)</td>
</tr>
</tbody>
</table>

### Figure 1. Scatterplots of preoperative eCrCl using 14 previously published models vs mCrCl from 24-hour urine collections. Perfect model would have all points on diagonal line defined by y = x. Linear regression lines are shown.
estimating CrCl and identified the most accurate models. We then developed tools that can be applied preoperatively to predict renal function postoperatively. Finally, we validated these tools in an external data set.

**MATERIALS AND METHODS**

After receiving approval from the institutional review board a prospectively maintained renal tumor database was queried to identify patients who had undergone radical nephrectomy, partial nephrectomy or nephroureterectomy (laparoscopic or open) at our institution between March 2001 and February 2008. Patients on dialysis and those with acute renal failure, defined as Scr greater than 4.0 mg/dl, were excluded from analysis. A total of 359 patients were included in the study. We focused on renal function and, therefore, radical nephrectomy and nephroureterectomy are together referred to as total nephrectomy.

Postoperative renal function was assessed 3 to 4 months after surgery. Scr was measured with an enzymatic method using a Vitros® 5,1 FS chemistry system. CrCl was measured using a 24-hour urine collection and calculated using the equation, (urine creatinine in mg/dl × urine volume in ml)/(Scr × 1,440). Statistical analysis was performed using Stata®, version 8.2.

**Comparison of Equations to Estimate CrCl**

A subset of patients had mCrCl obtained before (159) and after (110) surgery. mCrCl was the standard used to assess the accuracy of 14 previously described models for estimating CrCl (see Appendix). To illustrate the degree of agreement between mCrCl and eCrCl scatterplots and Bland-Altman plots were generated for each equation to compare mCrCl and eCrCl in the preoperative and postoperative settings. The Bland-Altman plot is a scatterplot of the difference between eCrCl and mCrCl vs their average. ICC was calculated to quantify the agreement between mCrCl and each eCrCl. Pitman’s test was used to detect significant difference in variances when comparing mCrCl and eCrCl. To determine the most accurate predictive model for estimating mCrCl models with Pitman p < 0.05 were eliminated. From the remaining equations CGAW was identified as an accurate model and selected for use in

Figure 2. Bland-Altman plots of postoperative difference between eCrCl and mCrCl vs their average. Perfect model would have all points on line defined by y = 0.
Predicting CKD
Preoperative and postoperative CrCl was then calculated in all 359 patients using CGAW. Tables were created to show the risk of decreased renal function following total or partial nephrectomy. Normal renal function was defined as CrCl greater than 60 ml per minute and renal function was stratified into groups defined by the National Kidney Foundation. Because of the limited number of patients with stages 4 and 5 renal function, ie CrCl 15 to 29 and less than 15 ml per minute, respectively, these stages were combined. Fisher’s exact test was used to compare the risk of CKD after partial or total nephrectomy.

Modeling and Validation
Multiple linear regression analysis was performed to generate separate models for predicting renal function following total and partial nephrectomy. The postoperative decrease in renal function was the dependent variable. Preoperative and postoperative eCrCl was determined using CGAW. Backward selection linear regression analysis was performed with a significance level of 0.01 for removal. Variables assessed as predictors of decreased renal function were preoperative Scr, patient age, sex, percent function of the involved kidney, tumor size, height, weight, race, hypertension history and smoking history. In patients who underwent partial nephrectomy regression analysis was repeated after including warm ischemia time.

The same modeling steps were applied to the external validation set from the University of Chicago. A total of 12 outliers with standardized residuals exceeding ± 2.5 were removed from the set. Outliers were primarily patients with worse renal function before surgery than after surgery, suggesting that they presented with acute renal insufficiency. A total of 245 patients were included in the final validation set.

Postoperative eCrCl was calculated by subtracting the predicted decrease in CrCl from preoperative eCrCl. Models developed using the training set were subjected to validation using the external data set. Using the model

Figure 3. Scatterplots of postoperative eCrCl using 14 previously published models vs mCrCl from 24-hour urine collections. Linear regression lines are shown.
developed from the training set postoperative CrCl was predicted. The correlation coefficient R was calculated by comparing predicted CrCl and eCrCl. Scatterplots were generated to plot eCrCl and predicted CrCl. Validated models were used to create a Web based tool for using preoperative information to predict postoperative renal function after total or partial nephrectomy.

RESULTS
Table 1 lists patient characteristics. A total of 359 patients underwent radical nephrectomy (laparoscopic in 150 and open in 80), partial nephrectomy (laparoscopic in 91 and open in 18) or nephroureterectomy (laparoscopic in 18 and open in 2). In laparoscopic partial nephrectomy cases mean tumor size was 2.6 cm (range 0.6 to 5.4) and 51% of tumors were located on the posterior kidney surface, 47% were located anteriorly and 1 was completely central. Mean total operative time was 215 minutes (range 135 to 333) and mean warm ischemia time was 21 minutes (range 3 to 47). All margins were pathologically negative and renal carcinoma was identified in 66% of patients.

In patients who underwent total nephrectomy, including radical nephrectomy and nephroureterectomy, mean preoperative Scr was 1.1 mg/dl (range 0.6 to 2.5) and mean postoperative Scr was 1.4 mg/dl (range 0.7 to 3.5). In patients who underwent partial nephrectomy mean preoperative Scr was 1.1 mg/dl (range 0.6 to 2.5) and mean postoperative Scr was 1.2 mg/dl (range 0.7 to 3.5). End stage renal disease requiring dialysis did not develop in any patient who underwent any surgical procedure. Of the 159 patients with mCrCl available preoperatively 21 (13%) had CKD despite a normal Scr of less than 1.5 mg/dl.

Evaluation of Equations to Estimate CrCl
Figure 1 shows scatterplots of preoperative mCrCl vs eCrCl for each of the 14 equations. Bland-Altman plots were generated to compare preoperative mCrCl and eCrCl (fig. 2). Scatterplots and Bland-Altman plots were also generated to compare postoperative mCrCl and eCrCl (figs. 3 and 4). Table 2 shows the agreement between mCrCl and each
After nephrectomy:

Preoperative eCrCl of greater than 90 ml per minute was at 58% risk for CKD after total nephrectomy compared to a 15% risk in those who underwent partial nephrectomy (p < 0.001).

Table 2. mCrCl vs eCrCl

<table>
<thead>
<tr>
<th>Equations</th>
<th>Preop ICC (95% CI)</th>
<th>Preop p Value (Pitman)</th>
<th>Postop ICC (95% CI)</th>
<th>Postop p Value (Pitman)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGAW</td>
<td>0.73 (0.66–0.80)</td>
<td>0.936</td>
<td>0.69 (0.59–0.79)</td>
<td>0.753</td>
</tr>
<tr>
<td>Mawer</td>
<td>0.74 (0.66–0.81)</td>
<td>0.950</td>
<td>0.69 (0.59–0.79)</td>
<td>0.421</td>
</tr>
<tr>
<td>Björnsson</td>
<td>0.74 (0.66–0.81)</td>
<td>0.761</td>
<td>0.68 (0.58–0.78)</td>
<td>0.589</td>
</tr>
<tr>
<td>Hull</td>
<td>0.74 (0.67–0.81)</td>
<td>0.286</td>
<td>0.69 (0.59–0.79)</td>
<td>0.248</td>
</tr>
<tr>
<td>Martin</td>
<td>0.74 (0.67–0.81)</td>
<td>0.532</td>
<td>0.67 (0.57–0.78)</td>
<td>0.214</td>
</tr>
<tr>
<td>Gates</td>
<td>0.74 (0.66–0.81)</td>
<td>0.001</td>
<td>0.74 (0.65–0.82)</td>
<td>0.112</td>
</tr>
<tr>
<td>Wright</td>
<td>0.73 (0.66–0.80)</td>
<td>&lt;0.001</td>
<td>0.72 (0.63–0.81)</td>
<td>0.008</td>
</tr>
<tr>
<td>Jeliffe-1</td>
<td>0.70 (0.62–0.78)</td>
<td>&lt;0.001</td>
<td>0.70 (0.60–0.80)</td>
<td>0.008</td>
</tr>
<tr>
<td>Cockcroft-Gault</td>
<td>0.63 (0.54–0.72)</td>
<td>&lt;0.001</td>
<td>0.68 (0.59–0.79)</td>
<td>0.004</td>
</tr>
<tr>
<td>(adjusted wt)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edwards-Whyte</td>
<td>0.47 (0.35–0.59)</td>
<td>&lt;0.001</td>
<td>0.59 (0.46–0.71)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Jeliffe-2</td>
<td>0.52 (0.40–0.63)</td>
<td>&lt;0.001</td>
<td>0.58 (0.45–0.70)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Davis-Chandler</td>
<td>0.43 (0.30–0.56)</td>
<td>&lt;0.001</td>
<td>0.53 (0.40–0.67)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cockcroft-Gault</td>
<td>0.42 (0.30–0.55)</td>
<td>&lt;0.001</td>
<td>0.53 (0.40–0.67)</td>
<td>0.001</td>
</tr>
<tr>
<td>(ideal wt)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MDRD</td>
<td>0.41 (0.28–0.54)</td>
<td>&lt;0.001</td>
<td>0.51 (0.37–0.65)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

There was only a 4% risk of CKD postoperatively. However, patients with an eCrCl of between 60 and 89 ml per minute were at 58% risk for CKD after total nephrectomy compared to a 15% risk in those who underwent partial nephrectomy (p < 0.001).

Table 3. CGAW risk of decreased renal function

<table>
<thead>
<tr>
<th>eCrCl (ml/min)</th>
<th>No. Pts</th>
<th>Less Than 90</th>
<th>Less Than 60</th>
<th>Less Than 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater than 90</td>
<td>111</td>
<td>63 (57)</td>
<td>5 (4)</td>
<td>0</td>
</tr>
<tr>
<td>60–89</td>
<td>62</td>
<td>36 (58)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>30–59</td>
<td>61</td>
<td>13 (21)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greater than 90</td>
<td>42</td>
<td>5 (12)</td>
<td>3 (7)</td>
<td>0</td>
</tr>
<tr>
<td>60–89</td>
<td>33</td>
<td>5 (15)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>30–59</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Preoperative predictors of decrease in renal function

<table>
<thead>
<tr>
<th>Set R</th>
<th>Coefficient</th>
<th>p Value</th>
<th>Partial R²</th>
<th>Training</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>After nephrectomy:*</td>
<td>-0.377</td>
<td>0.001</td>
<td>0.0345</td>
<td>0.807</td>
<td>0.757</td>
</tr>
<tr>
<td>After partial nephrectomy:*</td>
<td>-0.276</td>
<td>0.028</td>
<td>0.891</td>
<td>0.848</td>
<td></td>
</tr>
</tbody>
</table>

Models for Predicting Renal Function Postoperatively

In patients who underwent total nephrectomy significant predictors of decreased postoperative renal function were age and weight (table 4). The predicted decrease in renal function was used to predict postoperative renal function. This approach demonstrated a high level of accuracy in patients in the training set (R = 0.807). When the model developed from the training set was applied to the validation set, the shrinkage (R²training set − R²validation set) was 0.078, indicating good model performance. In patients who underwent partial nephrectomy the model had an R of 0.891. Shrinkage was 0.075 when applied to the validation set. Figure 5 shows a plot of estimated CrCl and predicted CrCl using the validation set.

In the preoperative setting the warm ischemia time associated with partial nephrectomy is not known. However, this information is available immediately after surgery. Therefore, another model was constructed of patients who underwent partial nephrectomy that included warm ischemia time. In this model warm ischemia time was significant as a predictor of postoperative renal function (p = 0.010), while tumor size was no longer significant. Overall R in the training and validation sets was 0.900 and 0.858, respectively. Postoperative renal function may be estimated using the 3 models at http://www.roswellpark.org/Patient_Care/Specialized_Services/Renal_FUNCTION_Estimator. This website also allows users to estimate immediate CrCl based on 5 of the models identified in this study as accurate estimators of mCrCl.
DISCUSSION

Until recently radical nephrectomy was considered the standard treatment for solid renal tumors. However, patients who undergo nephrectomy are at risk for renal insufficiency. This risk was first highlighted by Lau et al, who compared radical nephrectomy to nephron sparing surgery in patients with unilateral renal cell carcinoma and a normal contralateral kidney. Overall survival and cancer specific survival did not differ between these 2 groups. However, at 10 years the cumulative incidence of chronic renal insufficiency, defined as Scr greater than 2.0 mg/dl, was 22.4% in the radical nephrectomy group and 11.5% in the nephron sparing group. McKiernan et al used the same definition for chronic renal insufficiency and also reported a significantly higher rate of kidney disease after radical vs partial nephrectomy (15% vs 0%).

Scr provides only an approximation of renal function. In our study 13% of patients with CKD based on mCrCl had Scr in the normal range. Renal function can be more accurately estimated using various models that recognize the effects of additional factors, such as age, weight, height, gender and race. A model to estimate renal function was first described in 1959 by Edwards and Whyte. Since then, numerous alternative models have been proposed. The accuracy of these models varies based on the clinical setting and patient characteristics. However, to our knowledge these models have never previously been validated for use in a population of patients with renal tumors.

In this study a subset of patients had CrCl measured using a 24-hour urine collection. mCrCl, considered the gold standard for this study, was used to identify 5 of the 14 models that accurately estimated CrCl, including the CGAW, Mawer, Björnsson, Hull and Martin formulas. To create models for predicting postoperative renal function CGAW was used to estimate renal function. The Cockcroft-Gault formula is one of the most commonly used models for estimating renal function in the medical literature. This model was originally developed in a white male population but it has been validated in a wide range of settings.

Although the MDRD model is commonly used in the kidney cancer literature, in the current study it was the poorest estimator of CrCl with an ICC of 0.41 in the preoperative setting and 0.51 in the postoperative setting. This may reflect the fact that the MDRD equation was developed in a population with preexisting renal disease. Furthermore, the MDRD population specifically excluded patients older than 70 years and those with insulin dependent diabetes. Such patient characteristics are common in the renal tumor population. Although a number of investigators have validated the MDRD equation in healthy adults with normal renal function, and in patients with diabetes, heart failure or cancer, others have reported that the MDRD equation is less accurate in certain ethnic groups and in acutely ill hospital patients.

Go et al reported a graded association between decreased renal function and the risk of adverse medical events. The current study defines the likelihood of CKD after partial or radical nephrectomy, giving clinicians a tool for counseling patients who do not have an absolute indication for nephron sparing surgery. Table 3 can be used to look up the risk of a lower stage of renal function following surgery. In patients with normal renal function (CrCl greater than 90 ml per minute) who underwent radical ne-
phrectomy CKD with CrCl less than 60 was rare at 4%. However, 58% of patients with CrCl between 60 and 89 ml per minute had CKD following nephrectomy. In contrast, CKD developed in only 15% of patients who underwent partial nephrectomy. Mean tumor size was slightly smaller and had a higher proportion of female patients and black patients. Therefore, tumor size was associated with worse postoperative renal function when warm ischemia time was known, tumor size was replaced by warm ischemia time as an independent predictor of postoperative renal function and repair the kidney.

Independent predictors of the decrease in renal function after nephrectomy were age and weight. In patients who underwent partial nephrectomy, tumor size was associated with worse postoperative renal function. When warm ischemia time was known, tumor size was replaced by warm ischemia time as an independent predictor of postoperative renal function. Therefore, tumor size in patients who undergo partial nephrectomy may be a surrogate for the warm ischemia time required to resect and repair the kidney.

The models to predict postoperative renal function described in this study were successfully validated with an external data set. The validation set had a higher proportion of female patients and black patients. Mean tumor size was slightly smaller and a higher proportion of patients underwent partial rather than radical nephrectomy. Despite these differences the models performed extremely well for predicting postoperative renal function in the validation set. Using the validated models we developed a Web based tool that predicts renal function after radical or partial nephrectomy. The Web based tool also estimates current CrCl using each of the 5 models validated in this study for use in patients with kidney tumors.

CrCl measured in a 24-hour urine collection was the benchmark against which various models were compared. This mCrCl is prone to collection inaccuracies. However, all patients received standardized counseling, including verbal and written instructions. We only evaluated immediate postoperative renal function and the long-term risk of CKD following surgery was not studied. Finally, tubular secretion can lead to the overestimation of renal function, particularly in patients with severe CKD. In conclusion, CGAW was 1 of 5 models that accurately estimated renal function in the population of patients with renal tumors.

**APPENDIX**

<table>
<thead>
<tr>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gates</strong></td>
</tr>
<tr>
<td>Male: [89.4 \times \text{Scr}^{-1.2} \text{mg/dl}} + [(65 - \text{age}) \times (0.447 \times \text{Scr}^{-1.1})]\times \frac{\text{BSA}}{1.73}] where BSA indicates body surface area</td>
</tr>
<tr>
<td>Female: [56 \times \text{Scr}^{-1.1} + [(65 - \text{age}) \times (0.3 \times \text{Scr}^{-1.1})]\times \frac{\text{BSA}}{1.73}]</td>
</tr>
<tr>
<td><strong>Wright</strong></td>
</tr>
<tr>
<td>Male: [rac{6,230 - (32.8 \times \text{age}) \times \text{BSA}}{(\text{Scr} \times 88)}]</td>
</tr>
<tr>
<td>Female: [rac{6,230 - (32.8 \times \text{age}) \times \text{BSA} \times 0.832}{(\text{Scr} \times 88)}]</td>
</tr>
<tr>
<td><strong>Martin</strong></td>
</tr>
<tr>
<td>Male: [rac{163 \times \text{ABW} \times (1 - (0.00496 \times \text{age}))}{(\text{Scr} \times 88)}], where ABW indicates actual body weight</td>
</tr>
<tr>
<td>Female: [rac{163 \times \text{ABW} \times (1 - (0.00496 \times \text{age})) \times (1 - 0.252)}{\text{Scr} \times 88}]</td>
</tr>
<tr>
<td><strong>Mawer</strong></td>
</tr>
<tr>
<td>Male: [rac{\text{ABW} \times [29.3 - (0.203 \times \text{age})]}{14.4 \times \text{Scr}}]</td>
</tr>
<tr>
<td>Female: [rac{\text{ABW} \times [25.3 - (0.175 \times \text{age})]}{14.4 \times \text{Scr}}]</td>
</tr>
<tr>
<td><strong>Bjornsson</strong></td>
</tr>
<tr>
<td>Male: [rac{[27 - (0.173 \times \text{age})] \times \text{ABW} \times 0.07}{\text{Scr}}]</td>
</tr>
<tr>
<td>Female: [rac{[27 - (0.175 \times \text{age})] \times \text{ABW} \times 0.07}{\text{Scr}}]</td>
</tr>
<tr>
<td><strong>Hull</strong></td>
</tr>
<tr>
<td>Male: [rac{145 - \text{age}}{\text{Scr} \times 3} \times \frac{\text{ABW}}{70}]</td>
</tr>
<tr>
<td>Female: [rac{\text{CrCl}_{\text{est}} \times 0.85}{\text{Scr}}]</td>
</tr>
</tbody>
</table>

(appendix continued)
## APPENDIX (continued)

<table>
<thead>
<tr>
<th>Equation</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
</table>
| **Cockcroft-Gault** (actual weight) | \[
\text{Male: } \frac{140 - \text{age} \times \text{ABW}}{\text{Scr} \times 72}
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.85
\] |
| **Jeliffe-1** | \[
\text{Male: } \left( \frac{100}{\text{Scr}} - 12 \right) \times \frac{\text{BSA}}{1.73}
\] | \[
\text{Female: } \left( \frac{80}{\text{Scr}} - 7 \right) \times \frac{\text{BSA}}{1.73}
\] |
| **Cockcroft-Gault** (adjusted weight) | \[
\text{Male: } \frac{\left(140 - \text{age} \times \text{ADBW} \right)}{\text{Scr} \times 72}
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.85
\] |
| **Jeliffe-2** | \[
\text{Male: } \frac{98 - 0.8 \times (\text{age} - 20) \times \text{BSA}}{\text{Scr} \times 1.73}
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.9
\] |
| **Edwards-Whyte** | \[
\text{Male: } \frac{94.3}{\text{Scr}}
\] | \[
\text{Female: } \frac{69.9}{\text{Scr}} + 2.2
\] |
| **Davis-Chandler** | \[
\text{Male: } \frac{140 - \text{age}}{\text{Scr}}
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.85
\] |
| **Cockcroft-Gault** (ideal weight) | \[
\text{Male: } \frac{\left(140 - \text{age} \times \text{IBW} \right)}{\text{Scr} \times 72}
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.85
\] |
| **MDRD** | \[
\text{Male: } 186.3 \times (\text{Scr})^{-1.154} \times (\text{age})^{0.293} \times (1.210 \text{ if black})
\] | \[
\text{Female: } \text{CrCl}_{\text{adv}} \times 0.742
\] |

**BSA** = \[
\left( \frac{\text{height} \times \text{ABW}}{3,600} \right)^{0.66}
\]

Male\text{ IBW} = 50 + \left[ 0.897 \times (\text{Height} - 152.4) \right]

Female\text{ IBW} = 45.5 + \left[ 0.897 \times (\text{Height} - 152.4) \right]

\text{ADBW} = \text{IBW} + 0.4 \times (\text{ABW} - \text{IBW})\text{ except if ABW < [IBW + (IBW \times 0.25)]}

### REFERENCES


These authors accomplished several things directed toward estimating renal function before and after partial or total nephrectomy with the goal of being able to predict which patients will and will not have CKD. The authors have done all the right things, including assessing a large number of predictive models, applying complete statistical analysis and validating their results and tools in an external data set.

Despite extensive statistical analysis of their data showing good correlation between eCrCl and mCrCl there is a major concern. If one looks at figures 1 and 4 demonstrating the scatterplots between mCrCl and eCrCl as well as the Bland-Altman plots showing eCrCl and mCrCl, it becomes apparent that there is indeed wide variation between the 2, especially in terms of decreased renal function according to stratification, as defined by the National Kidney Foundation. For example, if one looks at Cockcroft-Gault estimated CrCl in the postoperative state it is easy to see that approximately a third of all estimations are at least 30 cc per minute in variance compared to mCrCl. This difference can have a major impact on clinical decisions, such as the administration of gadolinium in patients who undergo MR

**EDITORIAL COMMENTS**

These authors evaluated several predictive models for CrCl in patients with renal tumors using 24-hour urine collection as the reference standard. They confirm that many patients with renal tumors have CKD despite normal Scr and CKD is much more common after radical nephrectomy than after partial nephrectomy (reference 1 in article). The authors also define risk factors for CKD after renal surgery and propose a predictive algorithm for this adverse event. A criticism is the use of CrCl as the reference standard since this can be biased by inaccurate collection and tubular processing after filtration. Direct measurement of GFR by iothalamate clearance is more accurate and it is now commonly used as the reference standard for these types of studies.

Nevertheless, this article is timely, considering several reports in the nephrology literature showing a dose related, independent correlation between CKD, and morbidity cardiovascular events and death in population based studies (reference 3 in article). Our focus in urology should be on optimizing renal function after surgery and not just avoiding dialysis. Many urologists still perform radical nephrectomy for most small renal masses, which is a policy that must be reconsidered.1

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**REFERENCE**

scans and its relation to poor renal function. A mis-
calculation of 30 cc per minute can easily change the
decision from MR to no MR. The same holds true for
the decision with regard to the administration or not
of various chemotherapeutic agents, such as cispla-
tin. This becomes more problematic when one con-
siders that the gold standard used by the authors,
that is CrCl, tends to overestimate GFR due to the
tubular secretion of creatinine and this phenomenon
becomes even more pronounced as renal function
decreases.1 One can then wonder whether simple
Scr is functionally as good as an estimate using
complex formulated measurements of CrCl? Also,
maybe the true gold standard for GFR, at least when
it is used as a scientific reference, should be old-
fashioned inulin or diethylenetetramine pentaacetic
acid clearance?
An interesting aside that the authors report is
that warm ischemia time is an independent predic-
tor of postoperative renal function. If this is true,
that fact may impact the value of minimally invasive
partial nephrectomy requiring warm ischemia time
vs standard open partial nephrectomy with cold
ischemia time. Perhaps further long-term studies
may answer this question.

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REFERENCE

REPLY BY AUTHORS

Serum creatinine provides a crude approximation
of renal function. In a well hydrated patient with nor-
mal kidney function, unrelated factors such as age,
sex and muscle mass affect Scr. We evaluated a
large number of equations that were developed to
more accurately estimate renal function than Scr
alone and used CrCl measured from a 24-hour urine
collection as the standard. Creatinine clearance may
not accurately estimate GFR, particularly in pa-
tients with advanced renal disease. However, the
majority of our patients had good renal function and
CrCl should approximate GFR.

One of our goals was to recommend an equation
for estimating renal function in a typical popula-
tion being treated for renal tumors. The Cockcroft-
Gault equation based on actual weight was highly
accurate. The MDRD equation, which is commonly
used in the urological literature, was one of the
least accurate models. Others have documented
that the MDRD equation is less accurate in pa-
tients with normal renal function.1,2 However, the
correlation between mCrCl and eCrCl was not per-
fected. Fortunately the correlation was higher in
patients with poor renal function, when an accu-
rate estimate is critical. In our practice when a
highly accurate assessment of renal function is
required, renal function is measured rather than
estimated.

REFERENCES
1. Rule AD, Larson TS, Bergstralh EJ, Slezak JM, Jacobsen SJ and Cosio FG: Using serum creatinine to estimate glomerular filtration rate: accuracy in good health and in