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# Predictive Model for the Optimal Glomerular Filtration Rate in Living Kidney Transplant Recipients

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ABSTRACT

Background. Recipient glomerular filtration rate (GFR) after living kidney transplantation (KT) is influenced by many factors. Defining the appropriate level of recipient GFR post-KT is helpful. The aim of this study was to establish a predictive model to estimate the optimal recipient GFR at 1 week post-KT.

Methods. We retrospectively analyzed 211 living KTs without delayed or slow graft function. Estimated GFR was calculated using the Cockcroft-Gault (CG) formula. Donor kidney volume was obtained from routine computed tomographic angiography (CTA) by work station GE (AW 4.20) program. Multivariate analysis was carried out with automated backward selection to establish the predictive model. The bias, precision, and accuracy of our model were also determined by application of the model to another 37 living KTs.

Results. In multivariate analysis, the significant parameters to predict recipient GFR were donor age ($P = .025$) and kidney volume ($P < .0001$) and both were incorporated in the predictive model; predicted CG recipient GFR = 28.325 + (donor kidney volume x 0.282) - (0.297 x donor age). The correlation coefficient ($R$) is 0.5. Application to another group revealed that our model had high precision (14.45 mL/min), small positive bias (0.24 mL/min), and high percentage (81%) of predicted value, which was within 30% of the observed recipient GFR post-KT.

Conclusion. Our predictive model included donor age and donor kidney volume and could be used to estimate the optimal recipient GFR post-KT. This could be helpful to identify early graft dysfunction and to make a decision if further invasive investigation such as allograft biopsy is necessary.

RECIPIENT outcome after kidney transplantation (KT) is influenced by many variable factors, which can be divided into recipient factors, donor factors, transplantation factor [1,2], and occurrence of acute rejection. Thus, the optimal recipient glomerular filtration rate (GFR) is varied among different recipient-donor pairs. A more frequent observation is the stabilization of serum creatinine at a level considered to be inappropriately high in the first few weeks after living KT, which is often used as the benchmark for identifying subsequent graft dysfunction and requiring a diagnostic work-up that may include an invasive procedure, such as kidney biopsy. The definition of "appropriate level" of recipient GFR post-KT is challenging. A retrospective study by Sberro et al established a predictive formula for the lowest possible creatinine level in living donated KT, which has correlation coefficient ($R^2$) = 0.47; but when we applied their formula to our patients we found correlation coefficient ($R^2$) = 0.14 (0.2222 in males and 0.222 in females) [3,4]. The aim of our study was to establish a multivariate predictive formula for estimation of the optimal recipient GFR post-KT to ascertain a simple mean of identifying patients with early allograft dysfunction who are in need of further investigation.

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**Table 1. Baseline Characteristic of Donors and Recipients**

| Parameter | Mean ± SD | Range |
|---|---|---|
| Donor | | |
| Male:female | 88:123 | |
| Age (y) | 31.9 ± 9.6 | 19–61 |
| BMI (kg/m$^2$) | 22.8 ± 3.2 | 15.6–32.1 |
| Prenephrectomy creatinine (mg/dL) | 0.8 ± 0.2 | 0.4–1.3 |
| eGFR before nephrectomy (mL/min/1.73 m$^2$) | 105.8 ± 24.8 | 61.9–188.4 |
| 24-h urine CrCl (mL/min) | 118.1 ± 24.3 | 77.0–178.6 |
| Renogram CrCl (mL/min) | 110.5 ± 20.0 | 73.2–165.0 |
| Kidney volume (cm$^3$) | 156.7 ± 27.0 | 76.6–234.6 |
| Serum Cr, 30 d post-KT (mg/dL) | 1.1 ± 0.3 | 0.6–1.8 |
| Open:laparoscopic nephrectomy | 99:107 | |
| Recipient | | |
| Male:female | 127:84 | |
| Age (y) | 39.8 ± 11.4 | 18–68 |
| Weight (kg) | 57.3 ± 10.2 | 35.2–87.9 |
| BMI (kg/m$^2$) | 21.7 ± 3.2 | 15.2–31.5 |
| Mismatch ≤3:>3 | 160:50 | |
| Warm ischemic time (min) | 2.8 ± 1.8 | 1–13 |
| Anastomosis time (min) | 40.4 ± 11.3 | 20–75 |
| Cr, 1$^{st}$ wk post-KT (mg/dL) | 1.3 ± 0.4 | 0.6–2.2 |
| CG-eGFR, 1$^{st}$ wk post-KT (mL/min/1.73 m$^2$) | 62.2 ± 17.1 | 29.2–120.9 |
| MDRD eGFR, 1$^{st}$ wk post-KT (mL/min/1.73 m$^2$) | 64.0 ± 20.0 | 30.3–133.9 |
| Relationship (1$^{st}$ degree:2$^{nd}$ degree: unrelated) | 173:19:19 | |

Abbreviations: eGFR, estimated GFR; CrCl, creatinine clearance.

## MATERIAL AND METHODS

### Patient Population

Medical records of donors and recipients who had living KT performed between January 2001 and June 2011 were reviewed for exclusion criteria, which were age younger than 15 years, patients who had delayed or slow graft function (defined as need for dialysis in the first week after transplantation or serum creatinine level increased or remained unchanged or decreased <10%/d during 3 consecutive days after the transplantation) [5], patients who had biopsy-proven acute rejection within 1 month after KT or had biopsy-proven chronic allograft nephropathy within 3 months, and patients who had postoperative surgical complication or other obvious causes of allograft dysfunction within 3 months.

**Table 2. Correlation Between Kidney Volume and Donor Factors**

| Parameter | Correlation Coefficient (*R*) | *P* |
|---|---|---|
| Donor BSA (m$^2$) | 0.588 | <.0001 |
| Donor BMI (kg/m$^2$) | 0.471 | <.0001 |
| Donor weight (kg) | 0.601 | <.0001 |
| Donor height (cm) | 0.345 | <.0001 |
| Donor urine CrCl (mL/min) | 0.267 | .003 |
| Donor CG eGFR before nephrectomy (mL/min) | 0.401 | <.0001 |

Abbreviation: BSA, body surface area.

### Data Collection

Donor data collection included age, gender, weight, height, body mass index (BMI), serum creatinine level before nephrectomy and day 30 after nephrectomy, and type of surgical procedure (open or laparoscopic nephrectomy). Creatinine clearance was estimated using the Cockcroft-Gault formula (CG) and/or 24-hour urine creatinine clearance. Renal scintigraphy using $^{99m}$TcDTPA (technetium-99m-diethylenetriaminepentacetic acid) was used to assess kidney function before donation. Donated kidney volume was obtained from routine computed tomographic angiography (CTA). Renal parenchymal outline, excluded collecting system, was manually edited using work station GE (AW 4.20) program to calculated kidney volume in cubic centimeter (cm$^3$) (Fig 1).

Recipient data collection included age, gender, weight, height, BMI, underlying disease, number of transplantations, number of HLA (A, B, and/or DR) mismatches, panel-reactive antibody (PRA) level, donor-recipient relationship, cold ischemic time, warm ischemic time, and anastomotic time. Recipient serum creatinine level was recorded at 1-week intervals until 12 weeks and was calculated for allograft GFR using the CG formula and 6 variable MDRD equations (modification of diet in renal disease study equation).

### Statistical Analysis

Continuous variables are presented as median with interquartile range or mean ± standard deviation (SD). Categorical variables are presented as frequency and percentage. Association between post-transplantation recipient serum creatinine level and each continuous variable was evaluated using Pearson correlation (normality data) or Spearman rank correlation (non-normality data). Multivariate analysis using backward stepwise linear regression model was applied. A $P$ value < .05 was considered to be statistically significant. The predictive accuracy of the formula was assessed by calculating the correlation coefficient, bias, and precision [6]. Statistical analysis was executed using SPSS version 17.0 (Chicago, Ill, United States).

## RESULTS

In this analysis 211 donor–recipient pairs were included. Baseline characteristics are shown in Table 1. Mean recipient creatinine and GFR were stable from the first week to 3 months post-KT, reflecting an uncomplicated transplantation. Kidney volume had a strong correlation with donor size and donor creatinine clearance ($P < .001$) as shown in Table 2. We found "gender effect" in that male donors resulted in better outcomes than female donors. This may be explained by the fact that male donors had larger kidney volume than female donors ($P = .002$). Univariate analysis revealed significant correlation between recipient CG-GFR and kidney volume, donor CG-GFR, and recipient BSA (body surface area) (Table 3).

Backward stepwise linear regression analysis yielded 7 formulae for prediction of recipient GFR. The first formula comprised 8 variables and had correlation coefficient ($R$) of 0.521, whereas the last one used 2 variables and had $R$ of 0.5. Thus, we selected the last model, which comprised 2 variables, because of similar correlation but easier to apply in clinical practice.

The model was predicted recipient GFR = 28.325 + (0.282 x kidney volume [cm$^3$]) – (0.297 x donor age [years]).