Original Article

Correlation between preoperative remaining kidney volume and chronic kidney disease after donor nephrectomy

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Abstract

Objective: The aim of this study was to evaluate whether preoperative remaining kidney volume correlates with renal function after a donor nephrectomy.

Material and Method: A total of 303 kidney donors who underwent donor nephrectomies at Ramathibodi Hospital in Bangkok, Thailand between January 2011 and December 2015 were retrospectively reviewed. The donors' preoperative kidney volumes were calculated from computed tomography angiographies of the renal artery. Each donor's demographic data, surgical approach (open/laparoscopic), donated kidney side (right/left), and post-operative renal function (creatinine level and eGFR) were collected and analyzed between the two groups.

Result: Seventy of the living kidney donors developed CKD. There were no statistical differences in the donated kidney side (p=0.371), surgical approach (p=0.549), donated kidney volume (p=0.087), donated kidney volume percentage (p=0.126), remaining kidney volume percentage (p=0.126), weight (p=0.056), height (p=0.355), and body mass index (BMI) (p=0.062) between the two groups. The donor age medians in the CKD group and non-CKD group were 48 years old [interquartile range (IQR)=42-53] and 35 years old (IQR=29-44), respectively. The mean preoperative remaining kidney volumes in the CKD group and non-CKD group, respectively, were 114.6 ml [standard deviation (SD)=16.6] and 122.2 ml (SD=21.1). There were statistically significant differences in age (p=0.000), gender (p=0.001), and preoperative remaining kidney volume (p=0.002) between the two groups. Multivariate analysis showed that gender, age, BMI, and remaining kidney volume exhibited significant odds ratios (OR=8.971, 1.109, 1.167, and 0.973, respectively); therefore, all of these variables were predictive risk factors for the development of CKD after a donor nephrectomy at the 1-year follow-up.

Conclusion: Preoperative remaining kidney volume, age, gender, and BMI were found to be correlated with CKD after a donor nephrectomy at the 1-year follow-up.

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Introduction

The number of kidney transplantations is increasing worldwide, and it has become the standard treatment for end-stage renal disease. Abecassis et al. reported that early kidney transplantation has shown more benefits in cost, outcome, and quality of life than the other renal replacement therapies available.[1] Another study showed that kidney transplantations from spousal and living unrelated donors exhibited higher graft survival rates than cadaveric transplantations.[2]

In Thailand, the prevalence of chronic kidney disease (CKD) has been increasing. The Thai Screening and Early Evaluation of Kidney Disease (SEEK) study showed that the prevalences of stage III-V CKD were 7.8% and 9.3% in males and females, respectively.[3] In 2012, the Thai Transplant Registry reported that 465 kidney transplants were performed in Thailand. Of those, 214 (46%) were living donor transplantations and 251 (54%) were deceased donor transplantations.[4] It has been observed that the number of kidney transplant procedures has increased considerably over the past 7 years.

The safety of the kidney donor is the most important issue in a transplantation procedure. However, some kidney donors develop CKD after a donor nephrectomy. Wu et al. studied the association between preoperative kidney volume and time to develop CKD after a radical nephrectomy. The outcomes revealed that a preoperative kidney volume of less than 144 ml was an independent predictor of postoperative CKD.[5] However, the donor population is not the same as patients undergoing radical nephrectomies; thus, we conducted this study in order to evaluate the correlation between the preoperative kidney volume and CKD after a donor nephrectomy.

Material and Method

Study Population

This retrospective study was approved by the Institutional Review Board of Ramathibodi Hospital in Bangkok, Thailand. In total, 303 kidney donors who underwent laparoscopic donor nephrectomies and open donor nephrectomies at the Ramathibodi Hospital between January 2011 and December 2015 were retrospectively reviewed. The patient characteristics, including age, sex, body weight, height, body mass index (BMI), donated kidney side, remaining kidney volume, preoperative creatinine (Cr) and estimated glomerular filtration rate (eGFR), and postoperative Cr and eGFR at the 1-year follow-up were recorded. We calculated the eGFR using the CKD Epidemiology Collaboration (CKD-EPI) formula, which is more accurate than the Modification of Diet in Renal Disease Study (MDRD) equation.[6] CKD was defined as an eGFR <60 ml/min/1.73 m^2.

All the kidney donors were sent for renal artery computed tomography angiographies (CTAs) before donation. Three kidney donors were excluded from this study due to different renal artery imaging modalities, renal artery CTAs from other hospitals, or incomplete medical records. After the kidney donors with the aforementioned conditions were excluded, 119 kidney donors who underwent open donor nephrectomies and 181 kidney donors who underwent laparoscopic donor nephrectomies were included. Of these patients, 107 were men and 193 were women, and their median age was 38 years old [interquartile range (IQR)=30.5-48]. At the 1-year follow-up, nine kidney donors were excluded from this study due to a lack of blood test results.

Imaging Procedures

The preoperative remaining kidney volumes were calculated from the renal artery CTAs using the Extended Brilliance Workspace system software, version 4.5.6.52040 (Philips Medical Systems, Markham, Ontario, Canada). The renal contours were drawn manually on each axial view slice. The collecting system, vessels in the renal sinus, kidney sinus fat, and cysts were excluded, and the volume was automatically calculated by the postprocessing software.

The renal volumes were independently measured by three technicians who were blinded to the patients' characteristics.

Statistical Analysis

Descriptive statistics are presented as a frequency, percentage, mean, standard deviation (SD), median, IQR, and range. Gender, age, donated kidney side, surgical approach, and preoperative remaining kidney volume were analyzed using univariate analyses and multivariate analyses to determine which of the factors contributed to the development of CKD after donation. Preoperative remaining kidney volume and eGFR were subjected to correlation analyses. All the data were analyzed using Stata software, version 14.2 (StataCorp LLC, College Station, TX, USA).

Result

Table 1 provides the clinical characteristics of the 300 kidney donors. All the donors were healthy and most were female (64.33%). The median age and mean BMI at donation were 38 years old and 24.05 ml/min/1.73 m^2. Most of the kidneys were donated from the left side, and laparoscopic left donor nephrectomy was the procedure most commonly performed (58.33%). The mean preoperative total kidney volume and mean preoperative remaining kidney volume were 243.67 ml and 120.66 ml, respectively. The percentages of the remaining kidney volume and donated kidney volume were 49.52% and 50.47%, respectively. The medians of the preoperative Cr and postoperative Cr at the 1-year follow-up were 0.62 mg/dl and 1.08 mg/dl, respectively. The medians of the preoperative eGFR and postoperative eGFR at the 1-year follow-up were 80.13 ml/min/1.73 m^2 and 70.60 ml/min/1.73 m^2, respectively.

Seventy of the donors had developed CKD at the 1-year follow-up. Table 2 provides the clinical characteristic of the 291 kidney donors divided into two groups: CKD and non-CKD. The statistical analysis showed that there were no statistically significant differences in the donated kidney side (p=0.371), surgical approach (p=0.549), donated kidney volume (p=0.087), donated kidney volume percentage (p=0.126), remaining kidney volume percentage (p=0.126), weight (p=0.056), height (p=0.355), and BMI (p=0.062) between the two groups.

The donor age medians in the CKD group and non-CKD group were 48 years old (IQR=42-53) and 35 years old (IQR=29-44), respectively. The mean preoperative remaining kidney volumes in the CKD group and non-CKD group were 114.6 ml (SD=16.6) and 122.2 ml (SD=21.1), respectively. There were statistically significant differences in age (p=0.000), gender (p=0.001), and preoperative remaining kidney volume (p=0.002) between the two groups.

Table 3 provides correlation analysis between variable VS CKD and correlation analysis between variable VS eGFR. All of the variables had a correlation with the development of CKD and eGFR (p-value <0.05). Further univariate analysis and multivariate analysis were conducted; the result is shown in Table 4. From the multivariate analysis, gender, age, BMI and remaining kidney volume had a significant odds ratio (p-value <0.05), and thus all of these variables are risk factors for predicting the development of CKD after donor nephrectomy at the 1-year follow-up. On the other hand, side of the donated kidney and surgical approach are not risk factors for predicting the development of CKD after donor nephrectomy at the 1-year follow-up.

Table 1. Kidney donor characteristics

Variable		n=300
Gender, n (%)		
	Male	107 (35.67)
	Female	193 (64.33)
Donated kidney side, n (%)		
	Right	52 (17.33)
	Left	248 (82.67)
Surgical approach, n (%)		
	Laparoscopic	181 (60.33)
	Open	119 (39.67)
Surgical approach and donated kidney side, n (%)		
	Laparoscopic R nephrectomy	6 (2.00)
	Laparoscopic L nephrectomy	175 (58.33)
	Open R nephrectomy	46 (15.33)
	Open L nephrectomy	73 (24.33)
Kidney volume (ml), mean (SD)		
	Total kidney volume	243.67 (39.69)
	Donated kidney volume	123.02 (20.86)
	Remaining kidney volume	120.66 (20.38)
Donated kidney volume percentage, mean (SD)		50.47% (2.23)
Remaining kidney volume percentage, mean (SD)		49.52% (2.23)
Age, median (range)		38 (30.5-48)
Weight (kg), mean (SD)		61.92 (11.87)
Height (cm), mean (SD)		160.18 (8.39)
BMI, mean (SD)		24.05 (3.76)
Preoperative renal function		
	Cr (mg/dl), median (range)	0.62 (0.45-0.77)
	eGFR (ml/min/1.73 m^2), median(range)	86.13 (68.80-105.6)
Postoperative renal function		
	Cr (mg/dl), median (range)	1.08 (0.95-1.33)
	eGFR (ml/min/1.73 m^2), median(range)	70.6 (60.2-79.6)

SD: standard deviation, L: left, R: right, BMI: body mass index, Cr: creatinine, eGFR: estimated glomerular filtration rate

Table 2. Kidney donor characteristics at the 1-year follow-up (n=291)

Variable	With in 12 months			95%CI	Stat
	eGFR ≥60 n=221	eGFR <60 n=70	P		
Gender, n (%)					
Female	154 (69.7)	34 (48.6)	0.001		Chi-squared test
Male	67 (30.3)	36 (51.4)			
Side, n (%)					
Right	42 (19.0)	10 (14.3)	0.369		Chi-squared test
Left	179 (81.0)	60 (85.7)			
Operation, n (%)					
Open	91 (41.2)	26 (37.1)	0.549		Chi-squared test
Laparoscopic	130 (58.8)	44 (62.8)			
Age, median (IQR)	35 (29-44)	48 (42-53)	0	38.01-40.47	Wilcoxon-Mann-Whitney test
Donated kidney volume, mean (SD)	123.9 (20.7)	119.1 (20.6)	0.087	120.4-125.2	T-test
Remaining kidney volume, mean (SD)	122.2 (21.1)	114.6 (16.6)	0.002	118.1-122.7	T-test
Donated kidney volume percentage, mean (SD)	50.4 (2.3)	50.8 (2.2)	0.126	50.22-50.74	T-test
Remaining kidney volume	49.6 (2.3)	49.2 (2.2)	0.126	49.26-49.78	T-test
percentage, mean (SD)					
Weight (kg), mean (SD)	61.78 (12.82)	65.33 (11.83)	0.056		
Height (cm), mean (SD)	160.66 (9.05)	161.86 (8.28)	0.355		
BMI, mean (SD)	23.81 (3.83)	24.85 (3.60)	0.062		

Stat: statistical analysis, CI: confidence interval, SD: standard deviation, IQR: interquartile range,

BMI: body mass index, eGFR: estimated glomerular filtration rate

Table 3. Correlation analysis between variable VS CKD and correlation analysis between variable VS eGFR

Variable	Correlation of CKD		Correlation of eGFR	
	r	p-value	r	p-value
Gender (Female vs Male)	0.265	0	-0.184	0
Side (Right vs Left)	0.081	0.011	-0.115	0
Surgical approach (Open vs Laparoscopic)	0.07	0.029	-0.155	0
Age	0.425	0	-0.511	0
Remaining kidney volume	-0.098	0.002	0.14	0
Weight	0.173	0	-0.184	0
Height	0.085	0.007	-0.115	0
BMI	0.165	0	-0.115	0

Table 4. Univariate and multivariate analyses showing the odds ratios (ORs) of the variables

Variable	Univariate		Multivariate	
	OR (95%CI)	p-value	OR (95%CI)	p-value
Gender (base=female)	-			
Male	3.310 (2.06-5.31)	0	8.971 (4.74–16.95)	0
Age (years)	1.093 (1.06-1.12)	0		
Weigh (kg)	1.038 (1.02-1.05)	0		
Height (cm)	1.030 (1.00-1.06)	0.026		
BMI	1.107 (1.03-1.18)	0.003	1.167 (1.06-1.27)	0.001
Side (base=right)				
Left	1.677 (0.87-3.20)	0.118		
Operation type (base=open)				
Laparoscopic	1.479 (0.91-2.39)	0.111		
Remaining kidney volume (ml)	0.982 (0.96-0.99)	0.019		

CI: confidence interval, BMI: body mass index

Discussion

In this study, preoperative remaining kidney volume was a predictive factor for the development of CKD after a donor nephrectomy. Similarly, Yakoubi et al. reported that the preserved kidney volume in a living kidney donor was an independent predictor of the donor's remaining renal function 1 year after a living donor nephrectomy.[7]

The univariate and multivariate analyses demonstrated that the factors contributing to the development of CKD after a kidney donation include not only the preoperative remaining kidney volume, but also age, gender, and BMI. All of these variables are risk factors contributing to CKD development after a donation. Additionally, Rook et al. reported that a higher BMI and older age affected the reserve capacity after a donor nephrectomy.[8]

The present study did have some limitations. First, this study was retrospectively designed, which is known to be associated with some missing data and bias. Second, we used the CKD-EPI formula to calculate the eGFR, but some previous studies used the MDRD formula. All of the estimation equations exhibit less accuracy when compared to the chromium-51 labeled ethylenediaminetetraacetic acid radioisotope GFR.[9] However, Burballa et al. reported that the CKD-EPI equation correlates better with the technetium-99m-diethylenetriaminepentacetate measured GFR when accessing the renal function for donor screening purposes.[10]

Third, there is no standard method for measuring kidney volume. Many studies have used different types of equipment or software to measure kidney volume, such as total parenchymal three-dimensional renal volume, total parenchymal renal volume contouring, and renal cortical volume. Of these three methods, Gardan et al. claimed that the renal cortical volume appeared to be the best volumetric technique to use as a surrogate to scintigraphy for estimating the predonation split renal function and predicting postdonation renal outcomes.[11] However, reliability of the renal cortical measurement depends on the quality of the arterial phase necessary for the correct corticomedullary differentiation; therefore, in this study we used the parenchymal renal measurement. We used software to calculate the kidney volume by excluding the collection system, renal sinus vessels, kidney sinus fat, and cysts. Due to the different methods used for the kidney volume and eGFR measurements, it may be difficult to compare our results with those of other studies.

Conclusion

Preoperative remaining kidney volume, age, gender, and BMI were found to be correlated with CKD after a donor nephrectomy at the 1-year follow-up.

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