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Imaging Evaluation of Kidney Using Multidetector Computerized Tomography in Living-Related Renal Transplantation

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ABSTRACT

Background. Multidetector computerized tomography (MDCT) is lesser invasive than conventional angiography and has the advantage of assessment of vessels and surrounding anatomic variants before laparoscopic nephrectomy.

Methods. From May 2005 to March 2011, 62 consecutive living kidney donors of mean age 45.3 ± 12.7 years (range 24–70 y, male:female 26:36) underwent laparoscopic nephrectomy to paired recipients of mean age 44.8 ± 14.0 years (range 17–74 y, male:female 38:24). The clinical characteristics and laboratory data of donors and recipients were collected for analysis. Graft function as indicated by estimated glomerular filtration rate (eGFR) was obtained from the last stable visit of the donors and the best value displayed by the recipients.

Results. There was no significant correlation between CT kidney volume and and eGFR. By univariate analysis, donor age was associated with worse graft function (−0.51 mL/min lower eGFR per 1 year of donor age; $P < .0001$). Female sex and higher effective renal plasma flow/body mass index ratio were associated with better graft function; conversely, body weight and BMI were associated with poor graft function upon univariate and multivariate analysis. An ERPF of <220 mL/min and a donor age >45 y showed significantly lower eGFR. There was no effect of CT kidney volume <100 mL.

Conclusions. Our preliminary data suggest that CT kidney volume does not predict posttransplantation graft function, but MDCT is still important for analysis of anatomy before laparoscopic nephrectomy among living donors.

The shortage of organ donors has stimulated interest in living-related renal transplantation. Preoperative radiologic evaluation of kidney donors is used to select the patient and the kidney to be harvested. Traditionally, renal angiography and effective renal plasma flow (ERPF) have been used to evaluate potential kidney donors, but the former is invasive and the latter isotope dependent. Multidetector computerized tomography (MDCT) is less invasive than conventional angiography. It has the advantage of assessing the main vessels (renal vein, renal artery), ureteral structure, renal parenchymal lesions, renal cystic diseases, tiny stones, and surrounding anatomic variants in 1 test before laparoscopic nephrectomy.[1–3] In addition, MDCT can measure kidney volume, a more sensitive index of size than length as available from sonography.[4] Therefore, we used MDCT to select a suitable donor kidney and to measure CT volume compared with ERPF to predict donor and recipient prognosis.

MATERIALS AND METHODS

Patients

From May 2005 to March 2011, 62 consecutive living kidney donors underwent laparoscopic nephrectomy. All patients were referred to

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the radiology department for preoperative MDCT examination before the planned laparoscopic nephrectomy. This group consisted of 26 men and 36 women of overall mean age 45.3 ± 12.7 years (range 24–70). The protocol was the standard of care to enhance individual patient benefit at our institute over the past 6 years. The 62 paired recipients mostly received the donor's left kidney, with 1 right case owing to multiple vessels to the left kidney. The recipients included 38 men and 24 women of mean age 44.8 ± 14.0 years (range 17–74). The clinical characteristics and laboratory data of the donors and recipients were collected for analysis. The serum creatinine level and estimated glomerular filtration rate (eGFR) were obtained from the last stable visit in the donors and the best data in the recipients (Table 1). This study was approved by the Ethics Board of our institution (IRB TCVGH no. CE11155).

Imaging Protocol and Evaluation

All patients underwent CT angiography on a 64-MDCT scanner (Brilliance CT scanner; Philips Healthcare) in the supine position using 120 kVp and 300 mA from the upper to lower poles. The scanning parameters included a 64 × 0.625 mm collimation, 1-mm-thick reconstruction, 0.5-mm reconstruction increment, and 0.75-s rotation time. The scanning delay time was determined using the bolus-tracking technique. An arterial scan of the abdomen was initiated 5 seconds after a threshold enhancement of 150 HU was reached in the lumen of the abdominal aorta at the level of the diaphragm. One hundred milliliters of a nonionic contrast medium (iohexol [Omnipaque 350; GE Healthcare], iopromide [Ultravist 370; Bayer Schering], or iopamidol [Iomamiro 370; Bracco]) was administered at a rate of 3–4 mL/s using an automatic single-head power injector (Stellant; Medrad) through a 20-gauge IV catheter placed in an antecubital vein. Normal saline solution (50 mL) was injected at the same rate after the contrast administration. The examinations were interpreted by experienced abdominal radiologists at a Picture Archiving and Communication System workstation (Extended Brilliance Workspace; Philips Healthcare). The 3D images of bilateral kidneys were segmented and measured using the multiplanar reformation and tissue segmentation packages of the workstation. The standard parameters of tissue use Preset THC 250 and THW 300. A retrospective study evaluated renal function by MDCT among 45 paired donors and recipients.

Table 1. Clinical Characteristics of Donors and Recipients

	Donors (n = 62)	Recipients (n = 62)
Age (y)	45.7 ± 12.3	44.8 ± 14.0
Age range (y)	(24–70)	(17–74)
Age ≥45 y (%)	33 (53)	30 (48)
Female (%)	26 (42)	24 (39)
BMI (kg/m^2)	24.1 ± 3.4	23.5 ± 4.0
Donor initial sCr (mg/dL)	0.9 ± 0.2	
Donor initial eGFR (mL/min)	85.2 ± 15.1	
ERPF (mL/min)		
Right	266.1 ± 52.8	
Left	276.4 ± 60.4	
CT kidney volume (mL)		
Right	101.9 ± 20.8	
Left	102.1 ± 21.9	
sCr after transplantation (mg/dL)	1.0 ± 0.2	1.3 ± 0.4
eGFR after transplantation (mL/min)	70.3 ± 12.6	62.9 ± 17.6

Abbreviations: *BMI, body mass index; sCr, serum creatine; eGFR, estimated glomerular filtration rate; ERPF, effective renal plasma flow; CT, computerized tomography.*

Statistical Analysis

We analyzed clinical correlation of ERPF, MDCT kidney volume and body mass index (BMI) with renal function and patient prognosis. Statistical analysis used SPSS software version 11.5 (Chicago, IL). Statistical significance was defined as a P value of $<.05$.

RESULTS

Correlation of CT Kidney Volume and Estimated GFR

Total CT kidney volumes ranged from 119.2 to 326.7 mL (mean = 204.1). The reserved donor CT kidney volumes ranged from 54.5 to 155.2 mL (mean 101.9 ± 20.8). The recipient CT kidney volume ranged from 56.3 to 171.7 mL (mean 102.1 ± 21.9). The donor eGFR after transplantation ranged from 43.7 to 103.7 mL/min (mean 70.3 ± 12.6), and the best eGFR in the recipient ranged from 30.1 to 108.8 mL/min (mean 62.9 ± 17.6). As shown in Fig 1 there was no significant correlation between the total, donor, or recipient CT kidney volume and eGFR.

Correlation of ERPF and Estimated GFR

The mean predonation ERPF of the transplanted kidneys was 276.5 ± 60.4 mL/min, and of the reserved donor kidney ERPF was 266.0 ± 52.7 mL/min. After adjusting for donor and recipient sizes, the mean ERPF/BMI ratio was 4.5 ± 1.1 mL/min per kg/m^2. The Pearson correlation coefficient for the association between ratio of ERPF/BMI to eGFR in recipients was 0.325 (P = .010). The correlation of the reserved donor kidney and the recipient graft kidney was 0.233 (P = .011).

Correlation Between Transplanted Kidney Volume, ERPF, and Donor Age with Posttransplantation Renal Function (eGFR)

Univariate and multivariate linear regression analyses using the eGFR of stable donor function and best posttransplantation recipient graft function as the dependent variable sought to identify independent donor and recipient factors associated with better function (Table 2). On univariate analysis, donor age was associated with worse graft function (−0.51 mL/min lower eGFR per 1 year of donor age; $P <$ .0001). Female sex and higher ERPF/BMI ratio showed better graft function; conversely, body weight and BMI were associated with poor graft function (Table 2) in univariate and multivariate models. We could not demonstrate a correlation of donor CT kidney volume with eGFR. Recipients of transplanted kidneys that showed graft volumes <100 mL revealed no significant difference in posttransplantation eGFR at 6 months or 1, 2, or 3-years compared with patients who received larger-volume grafts (Fig 2A). However, recipients whose transplant ERPF was <220 mL were more likely to have a lower posttransplantation eGFR at 6 months and 1 year (Fig 2B). Recipients of

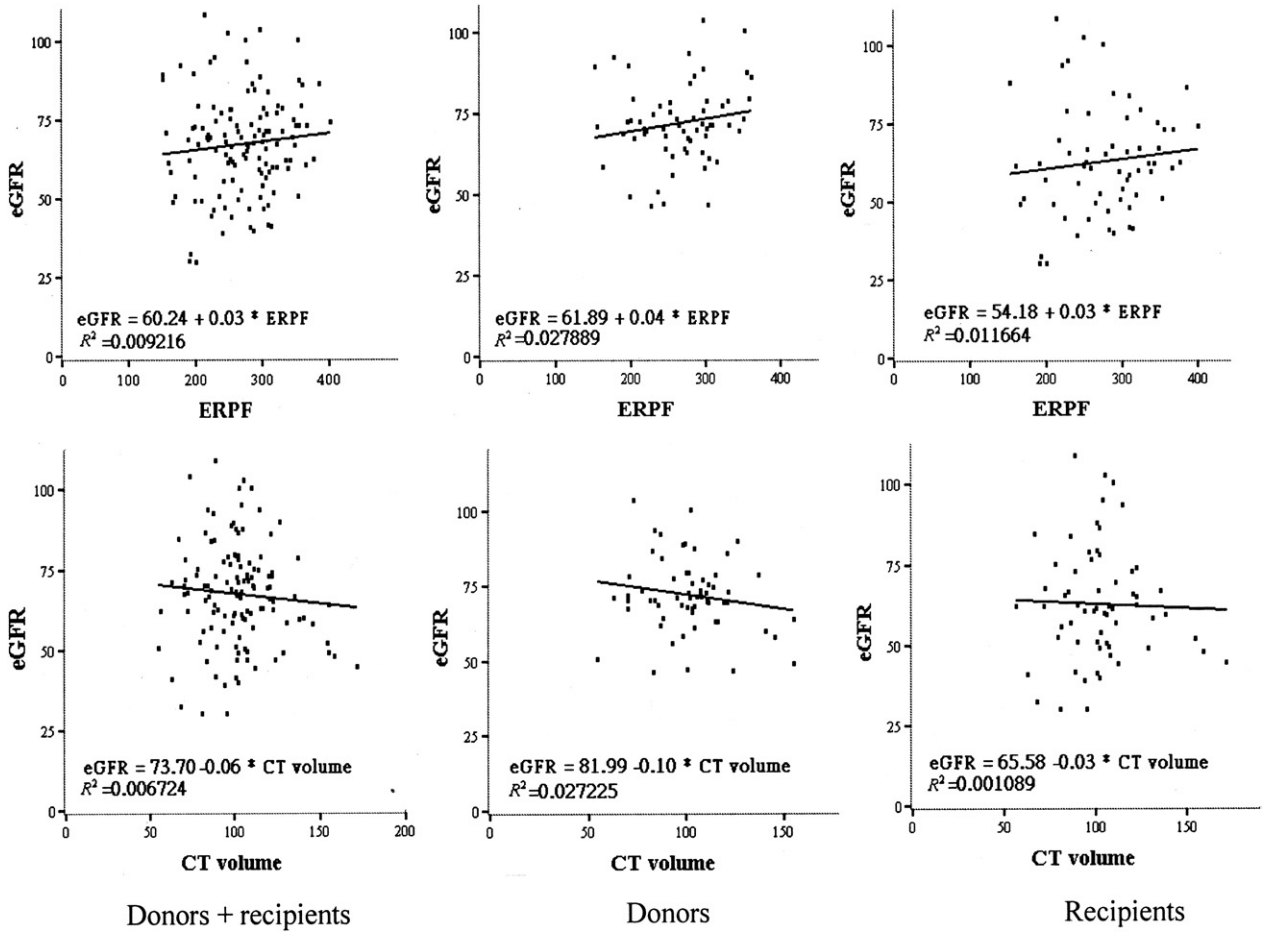

Fig 1. Plots showing correlation between estimated glomerular filtration rate (eGFR) and effective renal plasma flow (ERPF) and computerized tomographic (CT) kidney volume.

kidneys from donors >45 years old displayed significantly lower eGFRs at 6 months, and 1, 2, and 3 years compared with those obtained from younger individuals (Fig 2C).

Table 2. Donor Factors Independently Associated with Larger Total Kidney Volume and Higher Absolute GFR by Multivariate Linear Regression Analysis

	Beta	*P* Value	95% CI
Univariate			
Age	−0.51	.000	(−0.71, −0.32)
Sex	7.76	.006	(2.30, 13.22)
Body weight	−0.41	.000	(−0.62, −0.20)
BMI	−1.00	.010	(−1.76, −0.24)
ERPF/BMI	1.19	.011	(0.28, 2.09)
CT kidney volume	−0.06	.366	(−0.19, 0.07)
Multivariate			
Age	−0.51	.000	(−0.68, −0.33)
ERPF/BMI	0.87	.026	(0.10, 1.63)
CT kidney volume	−0.04	.496	(−0.14, 0.07)

Abbreviations: *CI, confidence interval; other abbreviations as in* Table 1.

DISCUSSION

MDCT angiography is important to understand the anatomy of blood vessels and surrounding structures before laparoscopic nephrectomy for living donation.[5] It also provides measurements of donor kidney volumes by 3D CT scanning.[6,7] Preoperative ERPF adjusted by body surface area and body weight ratios predicted short-term outcomes,[8] but preoperative CT kidney volume did not correlate with graft function among patients in Taiwan. An earlier report disclosed that transplantation of larger kidneys conferred an outcome advantage, suggesting that they should be preferred when selecting among otherwise similar living donors.[6] However, we could not demonstrate a similar finding. In some studies using CT with 3D reformations, there are high reader variations and low accuracy,[9,10] although the measurement tool has been validated to be more precise than manual tracings.

We evaluated factors that influence graft function, observing CT kidney volume to not show a significant linear correlation on univariate and multivariate analysis. It did

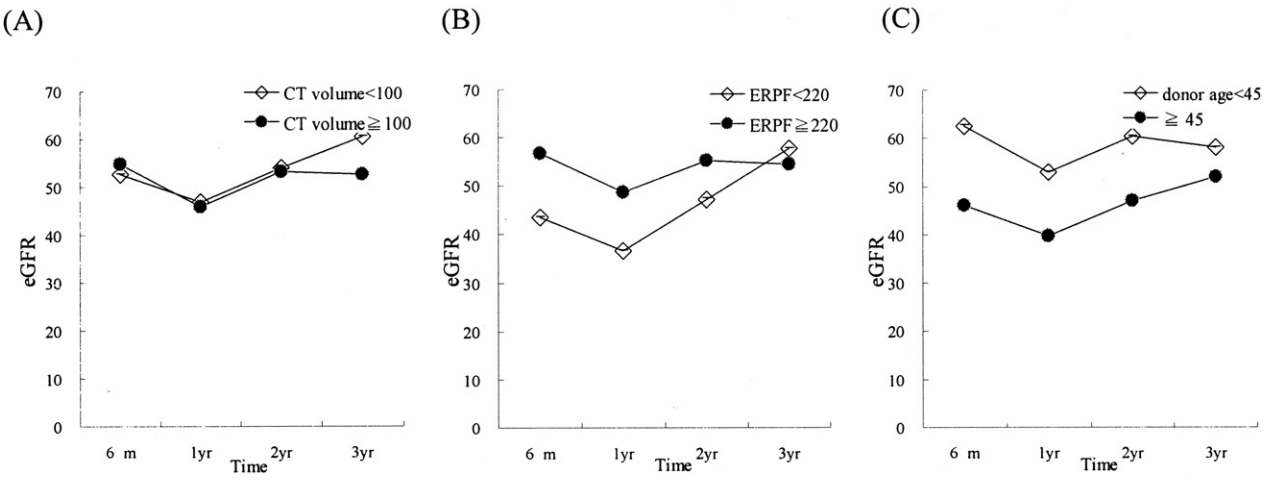

Fig 2. Graft function as measured by the Modification of Diet in Renal Disease estimation of glomerular filtration rate (eGFR) 6 months and 1, 2, and 3 years in **(A)** recipients of transplanted kidney volumes <100 mL and ≥100 mL ($P < .01$ for the first 2 time points), **(B)** ERPF <220 mL/min and ≥220 mL/min (P = NS for the last 2 time points), and **(C)** recipients of organs from donors <45 years and ≥45 years ($P < .001$ for each time point).

correlate with donor age, female sex, body weight, BMI, and ERPF/BMI ratio. In this study, we demonstrated that the ERPF and donor age, but not CT kidney volume, predicted early graft function. The limitations of our study are its retrospective design and a relatively small number of transplantations, older donors, and more female-to-male donations.

In conclusion, our preliminary data suggest that CT kidney volume does not predict posttransplantation graft function, but MDCT is still important to evaluate anatomy before laparoscopic nephrectomy for living donation.

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