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Is Computed Tomography an Alternative to Scintigraphy for Preoperative Evaluation of Living Kidney Donor Split Renal Function?

Bilgisayarlı Tomografi Canlı Böbrek Donörü Split Böbrek Fonksiyonunun Preoperatif Değerlendirmesinde Sintigrafiye Bir Alternatif mi?

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Abstract

Objective: This study aimed to evaluate whether computed tomography (CT) can replace scintigraphy for the preoperative evaluation of split renal function (SRF) and to determine the agreement between different CT volumetric measurement methods used so as to demonstrate this function.
Materials and Methods: The split renal function (SRF) percentage of living kidney donor candidates was determined by diethylenetriamine pentaacetic acid **(**DTPA) perfusion scintigraphy. The modified ellipsoid volume (MELV), semi-automatic total kidney volume (STKV) and semi-automatic renal cortex volume (SRCV) of the candidates who underwent contrast-enhanced CT were measured and the percentages of both kidney volumes were calculated. The inter-method agreement was evaluated using Pearson's correlation test and the Bland-Altman plot test.
Results: There was no correlation between the right and left kidney SRF and MELV (r=-0.033 and r=-0.092), MELV% (r=0.076 and r=0.076), STKV (r=-0.005 and r=-0.120), STKV% (r=0.175 and r=0.172), SRCV (r=-0.001 and r=0.130) and SRCV% (r=0.205 and r=0.183). There were significant correlations between the right MELV and STKV (r=0.855) and SRCV (r=0.813), and between the left MELV and STKV (r=0.787) and SRCV (r=0.770).
Conclusion: Although CT provided detailed preoperative anatomical information, volumetric measurements did not show agreement with SRF. The agreement of each 3 volumetric examinations within themselves made us think that disagreement with SRF was independent of the volumetric method chosen.

Keywords: kidney donor, donor evaluation, computed tomography

Öz

Amaç: Preoperatif split renal fonksiyonunun değerlendirilmesinde bilgisayarlı tomografinin (BT) sintigrafinin yerini alıp alamayacağının belirlenmesi ve BT'de kullanılan farklı hacimsel ölçüm yöntemlerinin bu fonksiyonu göstermedeki uyumunu saptamak amaçlanmıştır.
Gereçler ve Yöntemler: Canlı böbrek vericisi olmak üzere başvuran adayların DTPA perfüzyon sintigrafi ile split renal fonksiyon yüzdesi belirlendi. Kontrastlı BT yapılan adayların modifiye elipsoid formül, semiotomatik total böbrek hacmi ve semiotomatik korteks hacmi hesaplanarak her iki böbrek hacim yüzdesi hesaplandı. Yöntemler arası uyum Pearson korelasyon testi ve Bland- Altman plot testi ile değerlendirildi.
Bulgular: Sağ ve sol böbrek SRF ile; MELV (r= -0,033 ve r=-0,092), MELV% (r=0,076 ve r=0,076), STKV (r= -0,005 ve r=-0,120), STKV% (r=0,175 ve r=0,172), SRCV (r= -0,001 ve r=0,130) ve SRCV% (r=0,205 ve r=0,183) arasında korelasyon saptanmamıştır. Sağ MELV ile STKV (r=0,855) ve SRCV (r=0,813) arasında ve sol MELV ile STKV (r=0,787) ve SRCV (r=0,770) arasında belirgin korelasyon saptanmıştır.
Sonuç: BT, preoperatif anatomik ayrıntılı bilgi vermekle birlikte volümetrik ölçümler SRF ile uyum göstermemiştir. Her üç volümetrik incelemenin de kendi içerisinde uyumlu olmasının, seçilen volümetrik yöntemden bağımsız olduğunu düşündürmüştür.

Anahtar kelimeler: böbrek donörü, donör değerlendirmesi, bilgisayarlı tomografi

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Introduction

Renal transplantation is the best option for the treatment of end-stage renal disease [1]. Renal transplantation can be performed from a deceased or a living donor. Since the number of organ donations after brain death is insufficient in our country, the number of renal transplantations from living donors is higher [2].

Predonation evaluation of the living donor is important both in predicting the recipient's graft function and the kidney damage that may develop in the donor over the years after nephrectomy [3].

Systematic evaluation is of importance in the selection of an eligible donor prior to transplantation. Not only kidney functions but also other concomitant organ pathologies which affect the decision-making process are assessed. During the preparation estimated glomerular filtration rate (eGFR), 24-hour urine creatinine clearance (CrCl), 24-hour urine proteinuria, and microalbuminuria are used to determine kidney functions and/or damage [4].

Split renal function (SRF) demonstrates the performance distribution of each kidney, and usually the less functional kidney is selected for transplantation. Scintigraphic techniques performed using Tc-99m diethylenetriamine pentaacetic acid (DTPA), dimercaptosuccinic acid (DMSA) or mercapto-acetyl-triglycine (MAG-3) is being performed as gold standards for the scintigraphic evaluation of split renal functions [5].

Computed tomography is currently used as a noninvasive test that has replaced digital subtraction angiography for preoperative evaluation of the vascular structures of the donor candidate [6]. Morphological evaluation can be made, and also vascular variations can be demonstrated by CT. The fact that volumetric calculations can also be made by CT suggests that CT may replace scintigraphy for the evaluation of the SRF [7].

The primary aim of this study was to evaluate whether CT can replace scintigraphy for demonstrating split renal function, while the secondary aim was to determine the agreement between different CT volumetric measurement methods so as to demonstrate SRF.

Materials and Methods

Approval was obtained priorly from the local ethics committee of our hospital (Health Science University Kocaeli Derince Training and Research Hospital, Approval date and number: 2021/10). The requirement for written consent from patients was waived in accordance with the Council for International Organizations of Medical Sciences (CIOMS) guidelines. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Selection

Among living kidney donor candidates who were admitted to the organ transplant center of our hospital between January 2017 and December 2020, those with blood group incompatibility with the recipient, a positive lymphocyte cross-match test, diabetes mellitus, hypertension that cannot be treated with a single drug, chronic heart and lung disease, active malignancy, active infection, peripheral artery disease, bilateral renal stone, uncontrolled severe psychiatric illness, drug addiction, too severe cognitive impairment or mental retardation that made it impossible for the patient to understand the risks of organ donation, and marginal kidney functions were not considered eligible donor candidates [5].

The donor candidates with a blood group compatible with that of the recipient and a negative lymphocyte cross-match test were considered potential donors and underwent routine preoperative assessments. The available data were retrospectively evaluated.

Predonation Evaluation of the Kidney Function

Serum creatinine (SCr), endogenous 24-hour urine CrCl, and eGFR values were used to evaluate the renal functions of all donor candidates.

DTPA perfusion scintigraphy was used for the evaluation of split renal functions (SRFs) of the right and left kidneys which were determined as a percentage value for each kidney.

All CT examinations were performed using a 128-slice [Siemens Somatom Definition AS Plus, Siemens Healthcare GmbH, Erlangen Germany] or a 64-slice [Philips Ingenuity Core, Philips Medical Systems Nederland B.V.] CT device. CT examinations were performed in the arterial and venous phases after i.v. injection of a contrast agent to all patients.

Image Analysis

All images in the hospital's picture archiving and communication system (PACS) were retrospectively evaluated by the same specialist experienced in genitourinary radiology using the Philips IntelliSpace Portal software.

The contours of both kidneys were evaluated. Renal cysts or stones were noted. The number of renal arteries and the origin of accessory arteries were evaluated and recorded.

As the first volumetric method, the length, width (in coronal slices), and depth (in sagittal slices) were separately measured for each kidney at the hilum level to calculate the modified ellipsoid volume (MELV) using the ellipsoid formula (axbxcx π/2), where a,b,c are the lengths of all semi-axes of the ellipsoid, and π is the unchanged number Pi which is approximately equivalent to 3.14 [8].

As the second volumetric method, the renal parenchyma was drawn with mouse clicks by selecting the semi-automatic "segmentation" application in coronal, sagittal, and axial images acquired in the arterial phase. The collecting system, renal sinus adipose tissue, and parenchymal cysts, if any, were excluded from the measurement area. The semi-automatic total kidney volume (STKV) was calculated through the area marked by the software.

As the third volumetric method, similar to the second volumetric method, but only by marking the cortex, the semi-automatic renal cortex volume (SRCV) was calculated.

Split renal volume (SRV) was measured as MELV, STKV, and SRCV. These measurements were performed for each kidney separately, divided by the total volume, and multiplied by 100 to yield percentage values (%).

Table 1. Demographic characteristics and kidney function of donors

	Mean	Min	Max	Std Deviation
Age (year)	45,67	22	72	13,486
Length (cm)	170,47	159	192	8,688
Weight (kg)	76,6	56	97	11,230
BMI (kg/m²)	25,87	18	32	3,101
SCr (mg/dl)	0,78	0,59	1,13	0,130
eGFR (ml/min/1.73/m²)	102,27	56	130	16,265
CrCl (ml/min)	132,84	40	279	45,276
Proteinuria (mg/day)	154,44	34	370	72,791
Microalbuminuria (mg/day)	11,40	2	36	8,398

BMI: body mass index; SCr: serum creatinine; eGFR: estimated glomerular filtration rate; CrCl: creatinine clearance; min: minute

Statistical Analysis

Data were analyzed using the Statistical Package for Social Sciences (SPSS) version 17.0 software. Mean, minimum, maximum, standard deviation, and percentage values were used for the evaluation of descriptive results, and the one-sample Kolmogorov-Smirnov test was used to determine whether the numerical data were normally distributed or not. Pearson's correlation test was used to determine the correlation between the two continuous variables, and the Bland-Altman Plot test and one-sample t-test were used to evaluate the agreement between the CT volumetric methods. A p-value of <0.05 was considered statistically significant.

Results

The study included a total of 45 donor candidates including 19 (42.2%) female and 26 (57.8%) male participants with a mean age of 45.67 years. The mean height, weight, body mass index (BMI), eGFR, SCr, and CrCl, also urine protein, and microalbumin levels of the donor candidates are presented in **Table 1.**

Seven candidates had simple cortical cysts in the right kidney, while 9 had simple cortical cysts in the left kidney. The sizes of the cysts ranged between 6 mm, and 65 mm. One of the candidates had a stone in the upper pole calyx of the left kidney.

In indicated number of candidates, right kidneys of had 1 (n:38), 2 (n:6) and, 3 (n:1), while left kidneys had 1 (n:35), 2 (n:7), and 3 (n:3) renal arteries. The aberrant arteries originated from the right common iliac artery origin in 1, inferior mesenteric artery in 1 candidate, and abdominal aorta in 43 candidates (**Figure 1**).

Split renal function (SRF), modified ellipsoid volume (MELV), semi-automatic total kidney volume (STKV), and semi-automatic renal cortex volume (SRCV) and their percentages that were determined separately for right and left kidneys are presented in **Table 2** (**Figure 2**).

While there was no correlation between the STKV of both kidneys and SCr (p=0.24; r=0.55), a moderate correlation existed between STKV and CrCl (p=0.00; r=0.510).

There was no correlation between the right kidney SRF and right MELV (p=0.83, r=-0.033), MELV% (p=0.62, r=0.076), STKV (p=0.97, r=-0.005), STKV% (p=0.25, r=0.175), SRCV (p=0.99, r=-0.001) and SRCV% (p=0.17, r=0.205).

Figure 1. CT volume rendering imaging of two separate patients shows (A) the polar artery extending from the inferior mesenteric artery to the left kidney lower pole and (B) from the right common iliac artery to the right kidney lower pole

There was no correlation between the left kidney SRF and left MELV (p=0.54, r=-0.092), MELV% (p=0.62, r=0.076), STKV (p=0.43, r=-0.120), STKV% (p=0.25, r=.172), SRCV (p=0.39, r=0.130) and SRCV% (p=0.22, r=0.183).

There were significant correlations between the right MELV and STKV (r=0.855) and SRCV (r=0.813) and between the left MELV and STKV (r=0.787) and SRCV (r=0.770).

Discussion

Living-donor renal transplantation is an option for the treatment of end-stage kidney disease and the safety of a healthy kidney donor is important. The more functional kidney should remain in the donor to prevent possible post-donation complications. Therefore, anatomical and functional knowledge of both kidneys of the donor is required [5].

Although MAG3 or DTPA scintigraphic examinations are the gold standards in detecting SRF, some recent studies have suggested that CT or magnetic resonance volumetric examinations can also replace scintigraphy [9-13]. Cross-sectional imaging techniques demonstrate anatomical structures

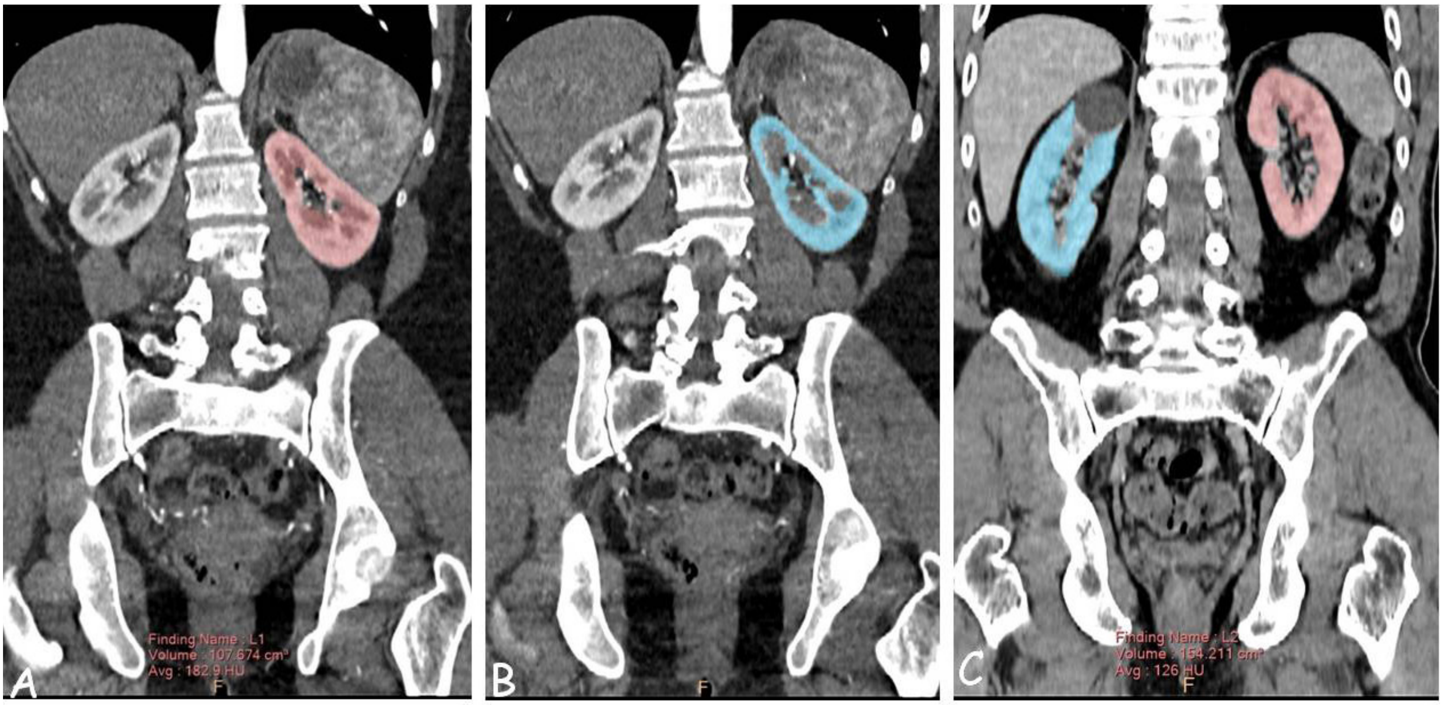

Figure 2. Left kidney total volume (A) and cortex volume (B) by semi-automatic measurement. In another patient, the right renal cyst was excluded in the total volume measurement calculated separately for each kidney (C)

Table 2. SRF and CT measurement values of both kidneys

	R Kidney (Mean±SD)	L Kidney (Mean±SD)
SRF%	47,47±3,1	52,36±3,1
Kidney length (mm)	99,49±10,1	98,29±13,5
Kidney width (mm)	48,24±5,4	52,24±6,2
Kidney depth (mm)	48,51±5,01	46,4±5,3
MELV (cm3)	123,73±30,9	127,69±40,4
MELV %	49,07±5,1	49,96±5,1
STKV	148,40±33,4	149,02±38,4
STKV %	49,71±3,1	49,31±3,1
SRCV	105,56±25,9	104,51±27,7
SRCV %	49,78±3,6	49,24±3,6

SRF: split renal function; MELV: modified ellipsoid volume; STKV: semiautomatic total kidney volume; SRCV: semiautomatic renal cortex volume

and vascularization of the kidney as well as provide volume information. In their meta-analysis of 19 studies investigating the usability of CT instead of nuclear SRF, Habbous et al. stated that CT could replace nuclear SRF [14]. In our study, volumetric measurements did not show agreement with SRF although CT demonstrated renal pathologies such as cysts and stones and preoperatively guided the surgeon by displaying vascular variations. The agreement of each 3 volumetric examinations in themselves made us think that disagreement with SRF was independent of the volumetric method chosen. Wahba et al. suggested that volumetric measurement of the renal cortex provides more precise information in the preoperative evaluation of SRF [7]. However, in our study, inconsistent measurements of the cortex volume have been obtained.

In their study, Habbous et al., stated that: SRV measured in computed tomography can replace SRF in the evaluation of living donor candidates. However, neither method is ideal. Understanding the reasons behind the 14% false-negative rate in the study is important to understanding the potential impact of reliance on SRV on clinical decision making [14].

Our study has some limitations, including its retrospective design, lack of inter- and intra-observer comparison, and failure to evaluate the postoperative renal functions of the donors.

Conclusion

Although CT volumetric methods have an agreement between themselves, they do not replace scintigraphy for split renal evaluation. CT-based volumetric measurements of split renal function should not be considered in upcoming guidelines for living kidney donation.

Ethics Committee Approval: The study was approved by the Ethical Committee of Health Science University Kocaeli Derince Training and Research Hospital. (Approval date and number: 11.02.2021/10).
Informed Consent: An informed consent was obtained from all the patients for research.
Publication: The results of the study were not published in full or in part in form of abstracts.
Peer-review: Externally peer-reviewed.
Authorship Contributions: Any contribution was not made by any individual not listed as an author. Concept- B.V., N.V.; Design- B.V., N.V.; Supervision- B.V., N.V., O.K.; Resources- B.V., N.V., O.M., O.K.; Materials- B.V., N.V., O.M., O.K.; Data Collection and/or Processing- O.M., O.K., B.V.; Analysis and/or Interpretation- B.V., N.V., O.K.; Literature Search- N.V., B.V., O.M.; Writing Manuscript- B.V., N.V.; Critical Review- B.V., O.M., N.V.
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