Predictors of Kidney Volume Change and Delayed Kidney Function Recovery After Donor Nephrectomy

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Purpose: To our knowledge the effects of preoperative kidney volume in living donors on the post-donation change in size and function of the remaining kidney have not been investigated. We studied the association between preoperative kidney volume, and volume change and delayed kidney function recovery in donors.

Materials and Methods: From 2007 to 2008 we investigated 222 living donors. Kidney volume before and 6 months after surgery was estimated using the voxel count method. We analyzed correlations of kidney volume with patient characteristics, kidney function and actual kidney weight. To identify predictors of the volume increase of the remaining kidney and predictors of delayed kidney function recovery we performed regression analysis.

Results: Mean ± SD total kidney volume was 311.9 ± 50.6 cc and it correlated with weight, body surface area and kidney function ($p < 0.001$). The mean volume increase in the remaining kidney was 27.6% ± 9.7% (range 4.5% to 66.1%). Younger age ($p < 0.001$) and lower preoperative volume of the remaining kidney ($p = 0.019$) were significant predictors of a greater increase in kidney volume on multiple linear regression analysis. Older age (OR 1.07, $p < 0.001$), higher body mass index (OR 1.20, $p = 0.008$), lower preoperative kidney volume of the remaining kidney (OR 0.98, $p = 0.003$) and a lower preoperative diethylenetetramine pentaacetic acid glomerular filtration rate in the remaining kidney (OR 0.95, $p = 0.017$) were significant predictors of delayed kidney function recovery on multiple regression analysis.

Conclusions: Kidney volume measured by the voxel count method was accurate and correlated with kidney function. Preoperative kidney volume is an independent predictor of the volume increase and delayed kidney function recovery in donors that could be used clinically.

Key Words: kidney transplantation; living donors; kidney function tests; tomography, emission-computed; organ size

Abbreviations and Acronyms

BMI = body mass index
BSA = body surface area
CCR = creatinine clearance
CG = Cockcroft-Gault
CT = computerized tomography
DTPA = diethylenetetramine pentaacetic acid
GFR = glomerular filtration rate
MDCT = multidetector CT
MDRD = modification of diet in renal disease

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Some reports show that the volume of a donor kidney is related to kidney allograft function.[1–3] Previously we reported that the ratio of kidney weight to recipient body weight is an independent factor in graft function.[4] To date the best method to directly determine graft weight and indirectly determine nephron mass is to weigh the graft. However, since weight after removal during surgery includes nonfunctioning tissue, such as the kidney vessels, central sinus fat, perirenal fat and ureter, actual kidney weight

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cannot be used to determine the functioning nephron mass.

Kidney function can be measured in several ways, such as serum creatinine (measured score), 24-hour CCR (measured score), GFR calculated by the abbreviated MDRD or the CG equation (calculated GFR) and ^{99m}Tc-DTPA kidney scintigraphy (scan). With the development of various imaging modalities, such as magnetic resonance imaging and MDCT, direct measurement of functioning kidney volume has become possible. Measurement of organ volume using MDCT, which generates a 3-dimensional reconstruction image, is accurate[5,6] and noninvasive.[7,8]

A few groups have reported that the volume of a healthy donor kidney is related to body parameters and 1 or 2 ways of assessing kidney function. However, to our knowledge the correlation of donor kidney volume with various kidney function measures and actual kidney weight has not been studied. Also, to our knowledge volume changes of the remaining kidney in donors after living donor nephrectomy, and the correlation between delayed kidney function recovery in donors and preoperative kidney volume have not been reported previously.

We evaluated the correlation of kidney volume measured by the voxel count method with patient characteristics, various kidney function measures and actual kidney weight, identified predictors of the donor kidney volume change after donor nephrectomy and assessed the role of preoperative kidney volume as a predictor of delayed kidney function recovery.

MATERIALS AND METHODS

Study Population

This prospective study was approved by the institutional review board at our institution. Enrolled in this study were 222 living adult kidney donors, including 106 men and 116 women, who underwent unilateral video assisted minilaparotomy nephrectomy for donation between January 2007 and December 2008. Patient characteristics, including age, gender, height, weight, BMI and BSA, were measured at hospital admission. Contrast enhanced CT was done preoperatively and 6 months postoperatively.

Measurement

Glomerular filtration rate. Four GFR assessments were measured in each patient preoperatively. 1) CCR was measured from a 24-hour urine collection and corrected for a standard BSA of 1.73 m^2. 2) GFR was estimated by a modified CG equation considering BSA (CG-GFR). 3) GFR was estimated by an abbreviated MDRD equation (MDRD-GFR). 4) ^{99m}Tc-DTPA kidney scintigraphy was done and corrected for a standard BSA of 1.73 m^2 (DTPA-GFR). At 6 months postoperatively 33 patients were lost to followup. MDRD-GFR in 189 donors was repeated. Delayed kidney function recovery was defined as estimated MDRD-GFR less than 60 ml/minute/1.73 m^2.

Kidney volume. Before and 6 months after surgery donor kidney volume was measured with 64-section helical CT scanners. Only 72 of the 189 patients who were followed at 6 months underwent CT. Images were obtained on the venous phase. Venous scans of the entire abdomen were done with a 60-second delay after starting the infusion of 2 cc/kg Iopamiro® 370 nonionic contrast material through an antecubital vein. Kidney volume was calculated using the Voxel Plus® 2.5 with a tissue segmentation tool. To calculate the voxel count volume of kidneys we analyzed images slice by slice at 1 mm thick, tracing the kidney boundaries at several levels, and excluding blood vessels, and perirenal and central sinus fat (fig. 1, *A*). Kidney volume was calculated by summing all voxel volumes within those boundaries (fig. 1, *B*). Donor kidney volume was measured by 1 radiologist and 2 urologists blinded to patient characteristics. The 3 sets of results were compared using the ICC. For analysis kidney volume in each patient was calculated as the mean of the 3 results. The volume measurement calculation in each kidney took less than 4 minutes.

Kidney weight. After nephrectomy the kidney was perfused by catheterizing the kidney artery with a cold

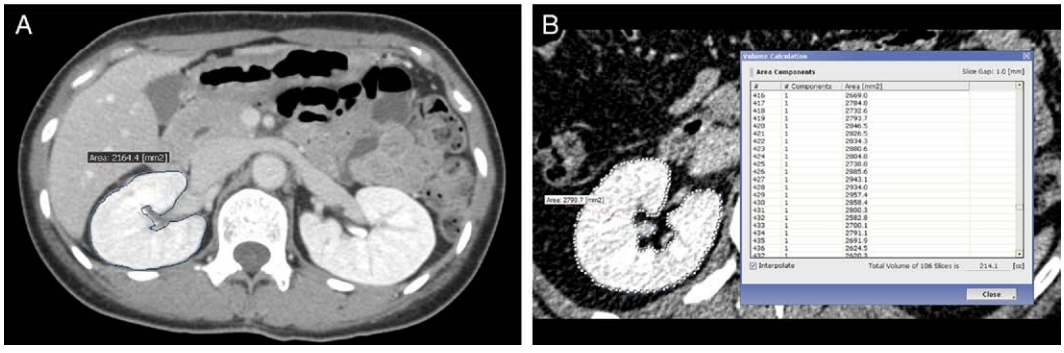

Figure 1. CT axial venous phase image shows method used to outline kidney surface, excluding perirenal fat, central sinus fat and great vessels (*A*). Kidney volume was calculated by summing all voxel volumes within those boundaries (*B*).