Comparison of 2 Computed Tomography–based Methods to Estimate Preoperative and Postoperative Renal Parenchymal Volume and Correlation With Functional Changes After Partial Nephrectomy

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OBJECTIVE To compare freehand scripting and semiautomated renal parenchymal volume measurements on preoperative or postoperative computed tomography scans and assess relationships between parenchymal volume loss and functional changes within the operated kidney after partial nephrectomy (PN).

MATERIALS AND METHODS Fifty patients (16 solitary kidneys, 34 bilateral kidneys) with renal tumors managed by PN with necessary studies for analysis were included. Freehand scripting and semiautomated threshold-based analysis were performed before and 4-12 months after PN to obtain preoperative normal parenchymal volumes, projected residual parenchymal volumes, and actual postoperative volumes. Glomerular filtration rate was determined by the Modification of Diet in Renal Disease 2 equation along with nuclear renal scan to provide split function for patients with 2 kidneys. Limits of agreement and Bland-Altman analyses were performed. The relationship between the amount of vascularized parenchyma preserved and renal function saved was correlated for each measurement method using Pearson correlation.

RESULTS The semiautomated method yielded estimates that were higher than freehand scripting by a mean of 14 cm^3 for estimation of preoperative normal parenchymal volume, 21 cm^3 for projected residual parenchymal volume, and 9 cm^3 for actual postoperative parenchymal volume. For the semiautomated method, correlation between the amount of normal parenchyma preserved and renal function saved was 0.52 (95% confidence interval [CI], 0.28-0.69; $P < .001$), and for the scripting method, correlation was 0.60 (95% CI, 0.39-0.76; $P < .001$).

CONCLUSION Semiautomated and freehand scripting measurements of parenchymal volumes were relatively consistent before and after PN, although the semiautomated approach tended to yield volumes that were approximately 5%-10% higher on average. Measurement of parenchymal volume changes by both approaches correlated significantly with functional changes after PN. UROLOGY 86: 80–86, 2015. © 2015 Elsevier Inc.

The goals of partial nephrectomy (PN) are to preserve as much renal parenchyma and function as possible, all within the context of negative surgical margins and a low complication rate.[1-2] Published guidelines establish PN as the reference standard for clinical T1a renal tumors.[3] More recently, the indications for elective PN have been expanded to larger tumors such as clinical T1b and T2a in carefully selected patients, and PN is always preferred when preservation of renal function is at a premium.[4-5]The main predictors of new baseline glomerular function rate (GFR) after PN are the quality and quantity of preserved parenchymal mass, with intraoperative ischemia playing a secondary role presuming that hypothermia or limited warm ischemia has been applied.[6-14] The quality of the preoperative kidney is predominantly nonmodifiable and dependent

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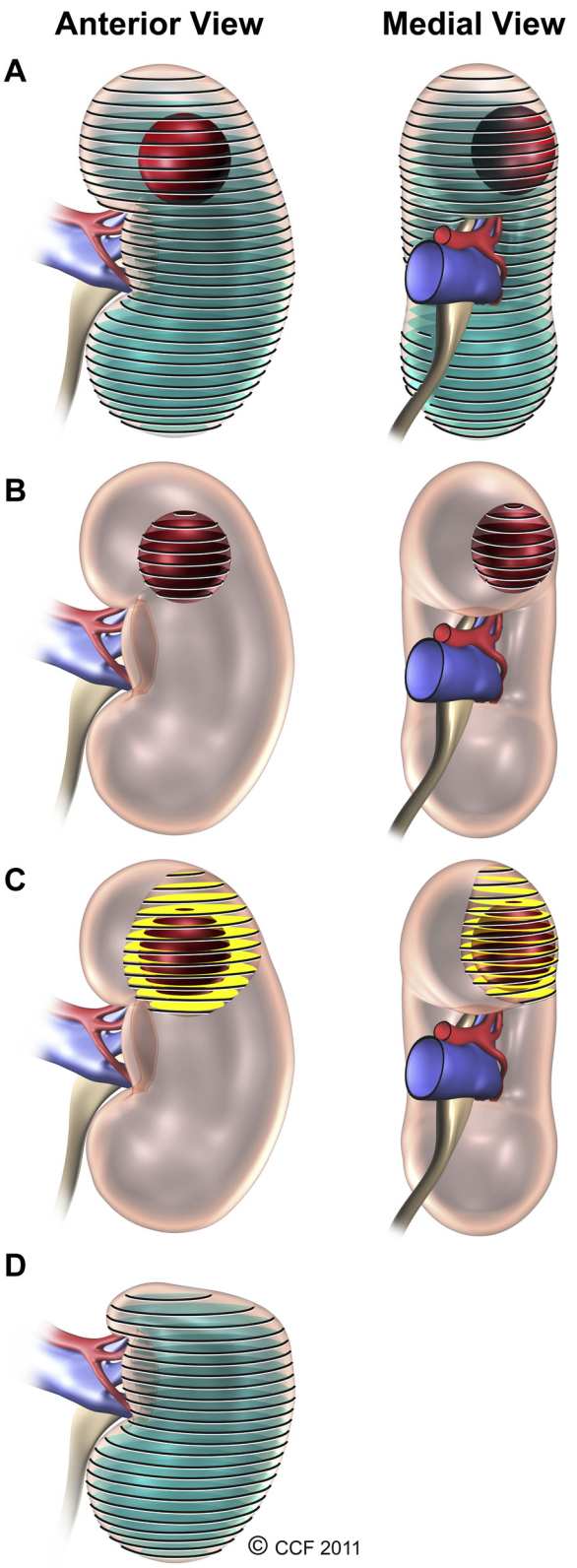

Figure 1. Schematic illustrating methodology of freehand scripting assessment of an anteriorly located, intrinsic tumor. In each figure, the kidney is viewed from its anterior and medial surfaces. Measurements are obtained on axial computed tomography scans at 3-mm intervals and summed to determine the relevant volumes of **(A)** renal parenchyma and tumor; **(B)** tumor alone; **(C)** tissue projected to be lost or devascularized during tumor excision and reconstruction, including a 5-mm rim of normal parenchyma, and any radially located tissue that would be devascularized; and **(D)** actual postoperative renal parenchyma. (Color version available online.) Reproduced with permission from Takagi T, et al, J Urology, 192:30-35, 2014.[13]

on age and pre-existing comorbidities. In traditional PN, the tumor is excised with a small rim of normal parenchyma and reconstruction is performed in a manner to preserve vascularity to as much of the remaining parenchyma as possible.[2,13] Loss of vascularized parenchymal mass, which is the key contributor to the decline of renal function after PN, is because of parenchymal excision but devascularization also contributes.[14] Most studies in this field have used computed tomography (CT) scans to estimate preoperative and postoperative vascularized parenchymal volumes, with some using a freehand scripting approach and others automated analysis based on sophisticated software to differentiate densities within the studies.[6-13] Comparative analyses for these 2 techniques are not available in the setting of PN.

Segmentation is central to these analyses and represents the process of dividing an image into regions with similar properties.[15] Manual segmentation (freehand scripting) is an accurate but labor-intensive method. Automatic segmentation of medical images is a difficult task because images are often complex and rarely have simple linear features. In particular, differentiation between hyperdense cysts, poorly enhancing tumors, partially enhanced collecting system, and normal vascularized parenchyma can be difficult.[15] However, semiautomated segmentation offers the potential for quicker, less labor-intensive results, and some have argued that it might eliminate potential subjectivity in measurement. This study compares freehand scripting and semiautomated measurements performed on preoperative and postoperative CT scans and evaluates for potential correlations between renal parenchymal volume preservation and changes in renal function.

MATERIALS AND METHODS

Patient Population

After obtaining approval from the institutional review board, we identified 50 patients (16 with a solitary kidney and 34 with 2 kidneys) out of 1834 who had PN performed at our institution between 2007 and 2013, for whom the GFR and parenchymal volume within the operated kidney could be established preoperatively and postoperatively. All GFR measurements and CT scans used for comparison were performed <2 months before and between 4 and 12 months after surgery.[6,13] The open and minimally invasive techniques used at our institution for PN have been described previously.[2,16] Cold or warm ischemia was applied according to surgeon preference. Tumor complexity was defined by the RENAL nephrometry score.[17]