Prospectively Estimating the Recoverability of Renal Function after Relief of Unilateral Urinary Obstruction by Measurement of Renal Parenchymal Volume

Mei Yang, PhD, Fei Gao, PhD, MD, Hui Liu, PhD, Hua Pang, MD, Yong Ping Zuo, BA, Tan Yong, BA

Rationale and Objectives: Renal parenchymal volume (RPV) has been suggested as an indicator of the potential functional residual capacity for a given kidney. The goal of this study was to determine whether the recoverability of renal function could be predicted by RPV as estimated by computed tomography (CT) before an operation.

Material and Methods: Eighty-two adult patients diagnosed with long-term chronic unilateral ureteral obstruction and a normal contralateral kidney were recruited for evaluation. RPV was measured by nonenhanced CT. Glomerular filtration rate (GFR) was measured by radioisotope renal scan. Animal models were used to validate use of the CT method to measure RPV. RPV and GFR values for all patients were obtained before surgical relief of the urinary obstruction and compared with those values obtained at 12 months postsurgery.

Results: There was no statistically significant difference found between RPV measured by CT or by the water displacement method. Among patient age, sex, and pre-RPV and pre-GFR of obstructed and contralateral kidney, pre-RPV and pre-GFR of obstructed kidney were the independent factors that best indicated recoverability of renal function. Pre-RPV correlated well with post-GFR (r = 0.68, $P < .01$). The cut-off point of pre-RPV to predict recoverability of renal function after the relief operation was 58.2 mL, as determined by receiver operating characteristic curve analysis.

Conclusion: Pre-RPV was the independent factor that determines recoverability of renal function. Renal function may stabilize or improve after relief of urinary obstruction when the pre-RPV value is ≥58.2 mL.

Key Words: Kidney; ureteral obstruction; spiral CT scan; organ size.

Urinary tract obstruction is a common condition that can occur at any age. In the United States, about 387 medical visits per 100,000 population were related to obstructive uropathy (1). Currently, two treatments are available for patients with urinary obstruction. One is surgical intervention, including ureteral stent placement, ureteroscopy, and nephrectomy, and the other is nonsurgical disease management, which includes treatments for infections or other symptomatic treatment, dietary modifications, increased fluid intake, and careful follow-up (2). Recoverability of renal function is the key consideration when making treatment selection. If renal function is likely to be restored or improved, surgical relief of the obstruction may be suggested, even though the initial loss of function is considerable. Otherwise, nonsurgical management, or even nephrectomy, may be preferable. Recoverability of renal function is difficult to predict before an operation, however, making it difficult for the physician to select the appropriate procedure. It would be of great value, therefore, to identify a physiologic indicator to predict the potential recoverability of renal function.

Glomerular filtration rate (GFR) is considered a sufficient indicator to predict renal function after relief of a urinary obstruction. The cut-off point for GFR that determines recoverability of renal function, however, has yet to be established (3–6). Moreover, it is expensive and time-consuming to measure GFR by radioisotope renography.

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From the Department of Anatomy, Institute of Neuroscience, Chongqing Medical University, Chongqing, People's Republic of China (M.Y., H.L.); Department of Urology, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, People's Republic of China and Department of Urology, Chongqing RenJi Hospital, Chongqing 400062, People's Republic of China (F.G.); Clinical and Administration Therapeutics Department, The University of Georgia, Augusta, Georgia (F.G.); Department of Radiology, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, People's Republic of China (H.P.); Department of Radiology, Chongqing RenJi Hospital, Chongqing 400062, People's Republic of China (Y.P.Z., T.Y.).
Received June 18, 2012; accepted October 10, 2012.
Address correspondence to: F.G. e-mail: gaofei667@yahoo.com

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The size of the renal parenchyma has also been suggested as an indicator of the potential functional residual capacity for a given kidney. If there is no renal disease present, the greater the thickness of the renal parenchyma, the better is the recovery of renal function after relief of obstruction (7–9). In hydronephrotic kidneys, however, the parenchymal thickness is irregular and measuring renal parenchymal thickness at one or more positions likely does not reflect the true amount of remaining renal parenchyma. Renal parenchymal volume (RPV) represents the total volume of the renal parenchyma. RPV index may provide a better reflection of remaining renal function. Thus, we propose that RPV may be a good index to predict recoverability of renal function in patients with unilateral ureteral obstruction (UUO).

RPV may be conveniently measured by ultrasonography and calculated by subtracting the renal sinus volume from the total renal volume. However, this technique is prone to inaccuracy and poor reproducibility (10,11). In contrast, the computed tomography (CT) method was demonstrated to be feasible and reliable to measure RPV value and to have a negligible error rate (12,13). The purpose of the present study was to explore whether pre-RPV measured by CT could predict recoverability of renal function following a relief operation in patients with long-term chronic UUO.

MATERIALS AND METHODS

Study Population

This was a prospective study that included 82 consenting adult patients (44 men and 38 women) with a mean age of 44.26 years (range 20–63 years). Patients with a diagnosis of long-term chronic UUO and having a normal contralateral kidney were enrolled. This study was approved by the hospitals' ethics committees, and an informed written consent was obtained from each patient. The cause of urinary obstruction was the presence of ureteral stones ($n = 82$). The number of proximal and distal ureteral stones was 28 and 54, respectively. Obstruction was successfully relieved in all patients by using a variety of endoscopic or open surgical procedures.

We excluded children and patients with bilateral urinary obstruction, UUO with an abnormal or absent contralateral kidney, persistent urinary tract infections, recurrent urinary tract obstructions, as well as those with no objective evidence of successful relief of obstruction after treatment. The contralateral kidney was considered normal if it had normal morphology and a split GFR above 40 mL/min per 1.73 m^2. We identified the cause of obstruction by CT prior to the surgical intervention and performed postoperative ultrasonography or abdominal radiography to verify the absence of stones following surgery. In cases where there was any doubt whether the stone(s) were completely removed, postoperative CT or intravenous urography (IVU) were carried out.

All patients underwent routine abdominal plain radiography, urinalysis, or ultrasonography at 3, 6, 9, and 12 months postoperation, to detect any urinary tract infections, recurrence of urinary tract obstruction or other factors that may have hindered recovery of renal function. RPV and GFR were measured by CT and radioisotope renography, respectively, before and 12 months after the operation.

Animal Model Study

To evaluate the accuracy of the CT method, we used an animal model. Ten ex vivo porcine kidneys were used. Renal pedicle tissue and all surrounding tissues were excised from all porcine kidneys without damaging the integrity of the renal parenchyma. As previously described, RPV values obtained by the water displacement method can be considered as the actual values (14). Measurement of RPV in ex vivo porcine kidney by the CT or water displacement methods, detailed below, was completed within 2 hours (Fig 1a–d) (14).

Assessment of RPV by Water Displacement Method

To determine RPV, each porcine kidney was immersed in 0.9% saline and the displaced solution was measured using a graduated cylinder. The measurements were repeated six times, and the mean of the six values was recorded (14).

Assessment of RPV by CT

All CT examinations were performed using a 16-slice multidetector spiral CT scanner (Siemens, Forchheim, Germany), without a contrast agent. A single operator, blinded to sample identifications, performed the CT measurements. Scans were acquired during a single breath hold, with the following parameters: 5-mm beam collimation; 10 mm/min speed; 80 to 90 mA; 130 kV; and a rotation time of 0.6 second. Images were reconstructed at 1.5-mm intervals. All CT images were transferred to a digital workstation where the RPV was calculated using the voxel count method. Briefly, the edge of the RPV was traced on each section and the total value of RPV was automatically calculated by adding all voxels lying within the boundaries of the kidney (Fig 1e–h). Thus, we made triplicate measurements of RPV with the instrument's accompanying software and used the mean of the three measurements as the RPV value.

Assessment of Single Kidney Renal Function by Radioisotope Renography

Renal function was assessed by radioisotope renal scans (Siemens, Symbia T_2, Forchheim, Germany). All operations were performed by the same individuals. After an intravenous bolus injection of ^{99m}Tc-diethylenetriamine pentaacetic acid (DTPA) into the forearm of the patient, dynamic imaging acquisition was carried out in the posterior position. Regions of kidneys and bladder were centered in the view of the gamma camera. The postinjection syringe was counted similarly to preinjection. Subtraction of the precount value from the postcount value provided the total injected dose. Region of interest (ROI) for each kidney was drawn manually on the