Poorly Functioning Kidneys Recover from Ischemia after Partial Nephrectomy as Well as Strongly Functioning Kidneys

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Purpose: Poorly functioning kidneys may not recover from ischemia as well as strongly functioning kidneys. This could impact surgical approaches to partial nephrectomy.

Materials and Methods: We analyzed the records of 155 consecutive patients treated with partial nephrectomy who underwent appropriate studies to facilitate analysis of function and parenchymal mass in the operated kidney, including computerized tomography and glomerular filtration rate measurement within 2 months preoperatively and 4 to 12 months postoperatively. Patients with a contralateral kidney also underwent renal scan in the same time frame to provide split renal function. Computerized tomography was done to measure functional parenchymal volume before and after partial nephrectomy. Recovery from ischemia, defined as percent glomerular filtration rate saved/percent volume saved, was considered 100% if all nephrons recovered from the ischemic insult.

Results: The median R.E.N.A.L. nephrotomy score was 8. Cold ischemia was used in 64 patients and limited warm ischemia was used in 91 (median 27 and 20 minutes, respectively). The median percent glomerular filtration rate saved in the operated kidney was 80% and the median parenchymal volume saved was 83%. The overall median rate of recovery from ischemia was 95%, including 100% for cold ischemia and 92% for limited warm ischemia. Recovery from ischemia was approximately 100% and was similar for all strata of preoperative estimated glomerular filtration rates in the operated kidney ($p = 0.24$), even in the warm ischemia subgroup.

Conclusions: Our results suggest that the quantity of parenchyma preserved is the main determinant of the postoperative glomerular filtration rate after partial nephrectomy as long as limited warm ischemia or hypothermia is used. Even poorly functioning kidneys recover well from the ischemic insult proportionate to the amount of parenchyma preserved.

Key Words: kidney; nephrectomy; ischemia; renal insufficiency, chronic; recovery of function

Abbreviations and Acronyms

CKD = chronic kidney disease
CT = computerized tomography
eGFR = estimated GFR
GFR = glomerular filtration rate
PN = partial nephrectomy
R.E.N.A.L. = radius, exophytic/endophytic properties, nearness of tumor to collecting system or sinus, anterior/posterior, hilar, location relative to polar lines

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PARTIAL nephrectomy is the reference standard for managing small renal masses (clinical T1a) and when preservation of renal function is potentially important, such as in patients with preexisting CKD, or multifocal or familial tumors.[1] PN is now performed using various techniques but the common objective is to preserve as much renal function as possible while

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still achieving strong oncologic outcomes along with minimal perioperative morbidity.[2,3] Potentially modifiable factors that can impact ultimate renal function after PN include the type and duration of ischemia, and the amount of parenchyma preserved during tumor excision and reconstruction.[4–12] Recent studies incorporating all of these parameters show that the number of preserved nephrons is the most important predictor of ultimate renal function and most preserved nephrons recover almost completely from the ischemic insult as long as limited warm ischemia or hypothermia is used.[6–15]

Poorly functioning kidneys can be a major challenge when PN is required. After a new baseline GFR is established after PN many patients with preexisting CKD can anticipate a progressive decrease in renal function in the next several years.[16,17] In a recent series such patients experienced a mean 4.7% annual decrease in GFR while those with more robust preoperative renal function were much more stable with an annual decrease of GFR of only 1%.[17] Thus, it is imperative that new baseline GFR be as high as possible in such patients.

However, a potential concern is that such kidneys may not recover from ischemia during PN as reliably given the reduced functional reserve. If this were true, approaches to minimize ischemia would be particularly important in this patient population. We analyzed the ability of different functional strata of kidneys to recover from the ischemic insult during PN.

PATIENTS AND METHODS

Patient Population

After receiving institutional review board approval we identified 1,834 PNs performed at our institution between 2007 and 2013, including those in 155 patients in whom GFR and parenchymal volume specifically in the operated kidney could be rigorously established preoperatively and postoperatively. PN techniques used at our institution were described previously. Intravenous mannitol was routinely administered as a renal protective maneuver. Cold or warm ischemia was applied according to surgeon preference and resection was begun immediately after clamping. The artery was always clamped while the vein was clamped selectively based on surgeon discretion.

The cohort of 155 patients comprised 59 with a solitary kidney. The remaining patients had a contralateral kidney. All serum creatinine measurements were made at a single clinical reference laboratory. GFR was estimated using the MDRD 2 (Modification of Diet in Renal Disease 2) equation.[18] In patients with a contralateral kidney GFR was estimated specifically in each kidney by preoperative and postoperative mercaptoacetyltriglycine nuclear renal scans. All measurements were made less than 2 months preoperatively, and between 4 and 12 months postoperatively.

Patients were stratified into 4 groups according to preoperative GFR in the ipsilateral kidney, including 30 or less, 31 to 45, 46 to 60 and greater than 60 ml/minute/1.73 m^2. Other clinical variables included age, gender, comorbidities, BMI, tumor size, R.E.N.A.L. nephrometry score, tumor stage, ischemia type and duration, and surgical approach. Complications were recorded using the Clavien scoring system.

Analyses

Volumetric. We used a standard renal mass protocol or abdominal CT protocols with the Sensation 16 or 64 multidetector scanner (Siemens, Erlangen, Germany) used for preoperative and postoperative imaging. Volume was estimated from axial scans in the venous phase reconstructed at 3 mm intervals. Parenchymal volume measuring techniques were described previously.[6]

Recovery from ischemia was defined as the degree to which the preserved parenchyma recovered its original function and was normalized according to parenchymal volume loss. This was calculated using the formula, percent function saved divided by percent parenchymal volume saved. Thus, recovery from ischemia would be 100% if all preserved nephrons recovered function completely.

Statistical. Data are shown as the mean ± SD, median with IQR, count or frequency with percent or proportion. Between group comparisons were made using the Wilcoxon rank sum test for continuous variables and the chi-squared test for categorical variables.

Multivariate regression analysis was done to assess the relationship between recovery and preoperative GFR subgroups adjusted for demographic and clinical covariates. Data transformation was applied to meet the assumption of normality. Effect of a covariate was based on dichotomized variables, or the first and third quartiles for continuous variables. All analyses and graphics were performed using R, version 2.15 (http://www.r-project.org/) with the rms package. Statistical significance was considered at $p < 0.05$.

RESULTS

Patient Characteristics

Table 1 lists baseline clinical and pathological features of the 155 patients who met study criteria. Our cohort was commensurate with conventional PN populations. Median age was 62 years, 64% of the patients were male and 59 (38%) had a solitary kidney. Renal scans were done preoperatively and postoperatively in patients with a contralateral kidney to facilitate analysis of functional recovery specifically in the operated kidney. Median R.E.N.A.L. score was 8, median tumor size was 3.2 cm and 85% of the tumors were stage pT1.

The surgical approach was evenly divided between open and minimally invasive techniques. Hypothermia was applied in 64 cases (41%) and