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Acute Kidney Injury after Partial Nephrectomy: Role of Parenchymal Mass Reduction and Ischemia and Impact on Subsequent Functional Recovery

Zhiling Zhang [a,b,†], *Juping Zhao* [a,c,†], *Wen Dong* [a], *Eric Remer* [a,d], *Jianbo Li* [a,e], *Sevag Demirjian* [a], *Joseph Zabell* [a], *Steven C. Campbell* [a,*]

[a] *Glickman Urological and Kidney Institute, Cleveland Clinic, Cleveland, OH, USA;* [b] *Department of Urology, Sun Yat-Sen University Cancer Center, State Key Laboratory of Oncology in South China, Collaborative Innovation Center for Cancer Medicine, Guangzhou, China;* [c] *Shanghai Jiao Tong University, School of Medicine, Ruijin Hospital, Department of Urology, Shanghai, China;* [d] *Imaging Institute, Cleveland Clinic, Cleveland, OH, USA;* [e] *Department of Quantitative Health Sciences, Cleveland Clinic, Cleveland, OH, USA*

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Abstract

Background: Acute increase of serum creatinine (SCr) after partial nephrectomy (PN) is primarily due to parenchymal mass reduction or ischemia; however, only ischemia can impact subsequent functional recovery.
Objective: We evaluate etiologies of acute kidney injury (AKI) after PN and their prognostic significance.
Design, setting, and participants: From 2007–2014, 83 solitary kidneys managed with PN had necessary studies for detailed analysis of function and parenchymal mass before/after surgery. AKI was classified by Risk/Injury/Failure/Loss/Endstage classification and defined by either standard criteria (comparison to preoperative SCr) or proposed criteria (comparison to projected postoperative SCr based on parenchymal mass reduction). Subsequent recovery was defined as percent function preserved/percent mass saved.
Intervention: PN.
Outcome measurements and statistical analysis: Predictive factors for AKI were evaluated by logistic regression. Relationship between AKI grade and subsequent functional recovery was assessed by linear regression.
Results and limitations: Median duration warm ischemia ($n = 39$) was 20 min and hypothermia ($n = 44$) was 29 min. Median parenchymal mass reduction was 11%. AKI occurred in 45 patients based on standard criteria and 38 based on proposed criteria, and reflected injury/failure (grade = 2/3) in 23 and 16 patients, respectively. On multivariable analysis, only ischemia time associated with AKI occurrence ($p = 0.016$). Based on the proposed criteria, median recovery from ischemia was 99% in patients without AKI and 95%/90%/88% for patients with grades 1/2/3 AKI, respectively. The coefficient for association between AKI grade based on proposed criteria and subsequent functional recovery was -4.168 ($p = 0.018$). Main limitation is limited patient cohort.
Conclusions: Parenchymal mass reduction and ischemia both contribute to acute changes in SCr after PN. Classification of AKI by proposed criteria significantly associates with subsequent functional recovery. However, more robust numbers will be needed to

† These authors contributed fully and equally to this work.

* Corresponding author. Center for Urologic Oncology, Room Q10-120, 9500 Euclid Avenue, Glickman Urologic and Kidney Institute, Cleveland Clinic, Cleveland, OH 44195, USA.
Tel. +1 216 444 5595; Fax: +1 216 636 0770.
E-mail address: Campbes3@ccf.org (S.C. Campbell).

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further assess the merits of the proposed criteria. While AKI is associated with suboptimal recovery, even patients with grade 2/3 AKI reached 88–90% of recovery expected.
Patient summary: Acute decline in function after partial nephrectomy associates with more prolonged ischemia time, and appears to impact subsequent functional recovery. However, most kidneys eventually recover strongly, even if their function is sluggish in the first few days after surgery.

1. Introduction

Functional recovery after partial nephrectomy (PN) has been a topic of considerable research and discussion in the field of localized kidney cancer [1,2], with recent studies demonstrating that new baseline glomerular filtration rate (GFR) after surgery can impact survival, particularly for patients with preexisting chronic kidney disease (CKD) [3–5]. Most studies have focused on ultimate recovery after PN, but recent literature has shown that acute kidney injury (AKI) can predispose to CKD [6]. This suggests that more careful scrutiny of the functional outcomes within the first few days after PN might be particularly informative [7]. Prior studies have shown that AKI after PN is primarily related to the duration rather than the type of ischemia, but the potential impact of AKI after PN has not been defined [7–9]. Acute increases in the serum creatinine (SCr) level after PN can be due to parenchymal mass reduction or ischemia, but only the latter can impact subsequent functional recovery.

AKI is currently stratified by fold increase of the SCr level above baseline, as detailed in the Risk/Injury/Failure/Loss/Endstage (RIFLE) classification scheme, with increasing grades associated with increased morbidity/mortality [10]. However, this approach does not take into account the reduction in parenchymal mass that occurs with PN, and therefore, may overestimate the incidence or severity of AKI in this setting. AKI after PN is most readily studied in patients with a solitary kidney [11], and in this study we analyze a cohort of these patients to define the incidence of AKI, risk factors for AKI, and the potential impact of AKI on subsequent functional recovery. In doing so, we propose a new classification scheme for AKI after PN that accounts for parenchymal mass reduction, and may allow for a more discerning assessment of the true impact of ischemia.

2. Patients and methods

2.1. Patient population

With institutional review board approval, we reviewed 2101 PNs performed at our institution from 2007–2014 and identified 83 patients with a solitary kidney for whom detailed analysis of parenchymal mass and function could be performed both before and after surgery. Inclusion required availability of cross-sectional imaging studies and SCr-based GFR estimates, which were derived from the Modification of Diet in Renal Disease-2 equation [12]. Preoperative studies were required to be within 2 mo of PN and postoperative studies between 4 mo and 12 mo after PN. Additional inclusion criteria included availability of SCr levels daily after surgery until peak SCr level was defined. All eligible patients were included in the analysis. During the same timeframe an additional 69 patients had PN for a solitary kidney at our institution but did not meet inclusion criteria, mostly due to unavailability of imaging/functional studies. A comparison of this cohort with the analyzed patients is provided in Supplementary Table 1. Patient and tumor characteristics were very similar in most respects, other than modest differences in Carlson comorbidity index, tumor stage, and ischemia type.

Decisions about open versus minimally invasive PN and use of warm versus cold ischemia were made by the primary surgeon based on individual tumor and patient characteristics. PN techniques utilized at our institution have been described previously [13,14]. Resection began immediately after clamping in all cases. The main artery or arteries were always occluded, while the vein was clamped selectively. For hypothermia, saline ice slush was utilized [14]. Demographic, clinicopathologic, and perioperative parameters were obtained by retrospective review, and R.E.N.A.L. complexity was defined as previously described [15].

2.2. Estimation of parenchyma mass and functional recovery

Venous phase of computed tomography or magnetic resonance scans were utilized for parenchymal volume estimates before/after surgery as outlined previously [16] for all patients with GFR greater than 30 ml/min/1.73m^2. Noncontrast studies were utilized to avoid contrast-induced nephropathy for patients with more severe CKD. Recovery from ischemia was assessed between 4–12 mo after PN and was defined as the percent function saved normalized by the percent parenchymal mass preserved [17].

2.3. Classification of AKI

AKI was classified by RIFLE [10] and defined by either standard criteria (comparison of peak SCr level to preoperative SCr level) or by proposed criteria (comparison of peak SCr level to projected postoperative SCr level based on parenchymal mass reduction) (Fig. 1). Grade 1 (risk) represented a 1.5–2.0 fold increase in SCr, grade 2 (injury) a 2.0–3.0 fold increase, and grade 3 (failure) any increase >3.0 fold or temporary need for dialysis. There were no instances of renal loss (dialysis required for >4 wk) or endstage renal failure in this series.

2.4. Statistical analysis

Continuous variables were expressed as median and interquartile range (IQR) and compared using Mann-Whitney test. Categorical variables were compared using the chi-square and Fisher's exact tests. Logistic regression was used for univariate and multivariable analysis for predictive factors for AKI. Association between recovery from ischemia and clinical parameters was evaluated using linear regression analysis. All p values were two-tail and $p < 0.05$ was considered significant. Data were analyzed using SPSS version 13.0 (SPSS Inc., Chicago, IL, USA).