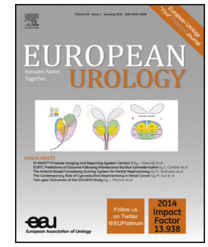
EUROPEAN UROLOGY XXX (2016) XXX–XXX

available at www.sciencedirect.com
journal homepage: www.europeanurology.com



European Association of Urology

Kidney Cancer

Acute Ipsilateral Renal Dysfunction after Partial Nephrectomy in Patients with a Contralateral Kidney: Spectrum Score to Unmask Ischemic Injury

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Article info

Article history:
Accepted April 12, 2016

Associate Editor:
Giacomo Novara

Keywords:
Partial nephrectomy
Acute kidney injury
Functional recovery
Ischemia
Parenchymal mass reduction

Abstract

Background: Acute ischemic injury in the operated kidney after partial nephrectomy (PN) is often masked by a functional contralateral kidney; however, there is no practical method to assess this and its prognostic significance has not been defined.
Objective: We propose a spectrum score to reflect the degree of ischemic insult in the ipsilateral kidney and study its relationship to subsequent functional recovery.
Design, setting, and participants: From 2007 to 2014, 243 patients with a functional contralateral kidney underwent PN with necessary studies for detailed analysis of function and parenchymal mass before and after surgery in the ipsilateral kidney. Based on split function and percent parenchymal mass preserved in the ipsilateral kidney, we determined: serum creatinine $(SCr)_{ideal\text{-}peak}$: expected peak SCr presuming no ischemic injury; and $SCr_{worstcase\text{-}peak}$: expected peak SCr presuming temporary complete non-function of the ipsilateral kidney. The acute ipsilateral renal dysfunction spectrum score was defined: (observed peak SCr – $SCr_{ideal\text{-}peak}$)/($SCr_{worstcase\text{-}peak}$ – $SCr_{ideal\text{-}peak}$). Subsequent functional recovery was defined: (percent function preserved)/(percent mass saved).
Intervention: PN.
Outcome measurements and statistical analysis: Factors associated with spectrum score and relationship between spectrum score and subsequent functional recovery were evaluated by linear regression.
Results and limitations: Median duration of warm ischemia ($n = 152$) was 21 min (interquartile range [IQR] = 15–27) and hypothermia ($n = 91$) 26 min (IQR = 23–30). Median parenchymal mass preservation was 83% (IQR = 74–91%). Warm ischemia and longer ischemia duration associated with higher spectrum score (both $p < 0.05$). Increased spectrum score (<25%, 25–50%, 50–75%, and >75% quartiles) had decreased functional recovery (98%, 94%, 90%, and 89%, respectively, $p < 0.001$). However, this trend was not observed in the hypothermia cohort. On multivariable analysis spectrum score and ischemia type significantly associated with functional recovery (both $p < 0.01$), while age and comorbidities failed to associate ($p = 0.3–0.7$).

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http://dx.doi.org/10.1016/j.eururo.2016.04.015

Conclusions: Acute ipsilateral renal dysfunction spectrum score unmasks the degree of ischemic insult in the operated kidney after PN and associates with functional recovery. While increased spectrum score associates with suboptimal recovery, even patients with a high spectrum score reached 89–90% recovery.

Patient summary: Acute functional decline after partial nephrectomy is difficult to evaluate in patients with two kidneys, but a proposed spectrum score can be used to evaluate this. Increased spectrum score reflects increased ischemia and may impact the functional recovery of the kidney.

1. Introduction

Partial nephrectomy (PN) is the reference standard for treatment of patients with localized renal masses primarily due to better preservation of renal function [1]. Recent studies suggest that new baseline glomerular filtration rate (GFR), which is achieved after early functional recovery, is an important prognosticator for stability of function and long-term survival [2–5]. Most studies have focused on functional outcomes a few to several weeks after PN, while events in the 1st few days after surgery, where the impact of ischemia can be greatest, have been understudied. However, recent literature suggests that acute kidney injury (AKI) can predispose to chronic kidney disease [6].

AKI is traditionally defined by a fold-increase of serum creatinine (SCr) above baseline level [7], but after PN, elevated SCr may due to both ischemia and loss of parenchymal mass. Our recent study utilized the solitary kidney model and advocated a new classification system for AKI after PN that accounts for loss of parenchymal mass [8]. Using traditional definitions of AKI, the incidence and degree of AKI was substantially overestimated, and AKI failed to associate with functional recovery. In contrast, when loss of parenchymal mass was accounted for, the true impact of ischemia was more reliably assessed, and degree of AKI then associated strongly with functional recovery [8].

Acute renal dysfunction related to ischemia after PN is much more difficult to study in patients with a functioning contralateral kidney. The incidence of AKI in this setting based on traditional definitions is as low as 2% [9], and this remains an understudied concept. We hypothesized that acute renal dysfunction can be quantified even in the presence of a functioning contralateral kidney, and provide a *spectrum score* that places each case between two extremes whereby the ipsilateral kidney either completely shuts down or experiences absolutely no ischemic insult. This proposed classification scheme for acute ipsilateral renal dysfunction (AIRD) takes into account loss of parenchymal mass to more accurately reflect the true impact of ischemia. In addition, we study factors that associate with AIRD spectrum score and subsequent functional recovery.

2. Patients and methods

2.1. Patient population

After approval by the Institutional Review Board, we reviewed 2101 PNs performed at our hospital from 2007 to 2014. A total of 243 patients with a functioning contralateral kidney for whom detailed analysis of parenchymal mass and function could be performed before/after surgery were included in this study [10]. All patients had preoperative/postoperative mercaptoactetyl-triglycine renal scans to provide split renal function. GFR was estimated using the Modification Diet in Renal Disease-2 equation [11]. Preoperative studies were required to be within 2 mo of PN and postoperative studies 4–12 mo after surgery. Additional inclusion criteria included availability of SCr levels daily after PN until peak SCr was defined. AKI was classified by Risk/Injury/Failure/Loss/Endstage [7] and defined as the ratio of peak SCr level to projected postoperative SCr level based on parenchymal mass reduction [8]. Grade 1 (risk) correlates with 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. Grade 4 (renal loss with dialysis >4 wk) or Grade 5 (endstage renal failure) events were not observed in this series.

Choices of open versus minimally invasive PN and use of warm versus cold ischemia were made by the primary surgeon based on individual patient/tumor characteristics. PN techniques have been described previously [12,13]. The renal artery was always clamped while the renal vein was occluded selectively. Demographic, clinicopathologic, and perioperative parameters were obtained by retrospective review, and R.E.N.A.L. was defined as previously described [14].

2.2. Estimation of parenchymal mass and functional recovery

Parenchymal volumes within the operated kidney were estimated from axial images within the venous phase by free-hand scripting (3-mm intervals) as outlined previously, with exclusion of the tumor from preoperative studies [10,15]. Recovery from ischemia (ie, functional recovery) within the operated kidney was assessed 4–12 mo after PN and defined as: (%function saved)/(%parenchymal mass preserved) [16].

2.3. Definition of acute ipsilateral renal dysfunction spectrum score

Extreme scenarios were considered. Extreme scenario 1: ischemic insult is severe and the ipsilateral kidney completely shuts down temporarily. Renal function is entirely dependent on the contralateral kidney, and SCr level will approximate a level that corresponds with the GFR of this kidney. This is defined as $SCr_{worstcase\text{-}peak}$. Extreme scenario-2: no ischemic insult and decrease of function is only due to loss of parenchymal mass. The corresponding SCr is defined as $SCr_{ideal\text{-}peak}$. Theoretically, for any individual patient undergoing PN, the observed peak SCr should fall into the range between $SCr_{ideal\text{-}peak}$ and $SCr_{worstcase\text{-}peak}$. The AIRD spectrum score was defined as: (observed peak SCr – $SCr_{ideal\text{-}peak}$)/($SCr_{worstcase\text{-}peak}$ – $SCr_{ideal\text{-}peak}$; Fig. 1).

2.4. Statistical analysis

Continuous variables were expressed as median and interquartile range and compared using Student *t* test for normally distributed data and Mann-Whitney U test for non-normally distributed data. Categorical