C-Index is Associated With Functional Outcomes After Laparoscopic Partial Nephrectomy

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Purpose: The C-index is a morphometric descriptor of renal masses that incorporates tumor size and site. We examined associations of the C-index with kidney function after laparoscopic partial nephrectomy.

Materials and Methods: We retrospectively reviewed the records of 131 patients who underwent laparoscopic partial nephrectomy for a single kidney tumor. We calculated the C-index from preoperative contrast enhanced computerized tomography images. Estimated glomerular filtration rate was calculated using the modification of diet in renal disease 2 equation. Nadir estimated glomerular filtration rate was calculated using peak serum creatinine within 7 days of surgery.

Results: The median C-index was 2.7 (range 0.7 to 9.6). The median preoperative and nadir estimated glomerular filtration rate was 78 (range 23 to 148) and 54 ml/minute/1.73 m^2 (range 15 to 127, $p < 0.001$). The mean ± SD total glomerular filtration rate decrease was 28% ± 16%. On univariate analysis we noted a positive correlation between log C-index and the nadir estimated glomerular filtration rate ($r = 0.29$, $p = 0.002$), and a negative correlation between log C-index and the percent decrease in the estimated glomerular filtration rate ($r = -0.4$, $p < 0.001$). On multivariate analysis the estimated glomerular filtration rate percent decrease was significantly associated with log C-index ($p = 0.005$) and warm ischemia time ($p < 0.001$) but not with tumor diameter or the preoperative estimated glomerular filtration rate. Of patients with a C-index of 2.5 or less 70% showed a 30% or greater decrease in the estimated glomerular filtration rate vs 32% of those with a C-index of greater than 2.5 (RR 2.2, $p < 0.001$).

Conclusions: The C-index is associated with the postoperative nadir estimated glomerular filtration rate and the percent decrease in the estimated glomerular filtration rate after laparoscopic partial nephrectomy. A C-index of less than 2.5 correlated with a 2.2-fold increased risk of a 30% or greater estimated glomerular filtration rate decrease after laparoscopic partial nephrectomy.

Key Words: kidney, nephrectomy, kidney function tests, laparoscopy, prognosis

Abbreviations and Acronyms

CI = C-index
CKD = chronic kidney disease
CT = computerized tomography
eGFR = estimated GFR
GFR = glomerular filtration rate
LPN = laparoscopic partial nephrectomy
SCr = serum creatinine
WIT = warm ischemia time

Submitted for publication April 23, 2010.

Study received institutional review board approval.

Supplementary material for this article can be obtained at http://my.clevelandclinic.org/urology/publications/publications.aspx.

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For another article on a related topic see pages 2540 and 2549.

DECREASED kidney function after partial nephrectomy is affected by numerous variables, including preoperative functional status, WIT and the percent of functional volume resection. Identifying preoperative risk factors to predict postoperative function can help optimize surgical planning. Tumor diameter is a factor strongly associated with postopera-

0022-5347/10/1846-2259/0
THE JOURNAL OF UROLOGY®

Vol. 184, 2259-2263, December 2010
Printed in U.S.A.
DOI:10.1016/j.juro.2010.08.031

tive GFR since increased diameter corresponds to prolonged ischemia time and a higher percent of functional volume loss.[1] CI is a recently reported descriptor that incorporates tumor size and proximity relative to the renal hilum, which are important when considering the technical challenge of resection.[2] CI correlates with WIT, which is an indicator of technical complexity, but to our knowledge its association with postoperative kidney function has not been evaluated. We describe the association of CI with postoperative nadir GFR and the maximum percent GFR decrease after LPN.

MATERIALS AND METHODS

We retrospectively reviewed the records of 131 consecutive patients who underwent transperitoneal LPN for a solitary tumor, as done by a single surgeon (ISG) between September 2003 and October 2005. This historical cohort had more prolonged WIT than contemporary cohorts.[3] Study inclusion criteria included a contrast enhancing renal tumor on CT, resection of a single kidney tumor by LPN and a radiologically normal contralateral kidney. Exclusion criteria included preoperative stage V CKD, solitary kidney, metastatic disease and multiple or bilateral tumors. Preoperative evaluation included medical history, physical examination, serum creatinine, urinalysis, chest x-ray and CT. SCr was measured daily after surgery until discharge home. The study primary end point was eGFR, calculated using the modification of diet in renal disease 2 equation, GFR in ml/minute/1.73 m^2 = $186 \times SCr^{-1.154} \times age^{-0.203} \times (0.742$ if female$) \times (1.210$ if black).[4] Postoperative peak GFR was calculated using the highest measured SCr within 7 days of surgery. CKD stage was defined by National Kidney Foundation KDOQI™ criteria.[5]

Kidneys were imaged using contrast enhanced CT with serial 3 mm step-sections. SIENET MagicView 300 software (Siemens, New York, New York) was used to analyze CT images. We measured CI in arterial contrast phase images, as previously described.[1] Image sections showing the kidney top and bottom borders were identified and image numbers were averaged to identify the middle plane. We assigned a vertical axial reference point to the center of an ellipse drawn around the kidney periphery in the middle plane. The image section showing largest tumor diameter, ie the tumor plane, was identified and the number of sections between the middle and tumor planes was recorded. This number was multiplied by section thickness in cm to determine distance (y). In the tumor plane the distance in cm between the central axial reference point and the tumor center was measured and recorded as distance (x). Tumor diameter was measured parallel to the line drawn to measure x and divided by 2 to obtain tumor radius (r). C was calculated using the Pythagorean theorem, $C = (\sqrt{(x^2 + y^2)})$, and divided by r to obtain CI. We used a Microsoft® Excel® spreadsheet for all data entry and automated calculation.

Statistical analysis was done with SAS® in collaboration with Cleveland Clinic Department of Quantitative Health Sciences staff. CI was log transformed to convert data to a normal distribution for regression analysis. A univariate linear regression model was fit to CI and peak GFR, and to CI and the percent decrease in GFR. A multivariate linear regression model was fit to CI and the percent decrease in GFR, accounting for other cofounders such as age, gender, tumor diameter, WIT, and intraoperative and postoperative complications. In all analyses the null hypothesis was rejected at $p < 0.05$.

RESULTS

Table 1 lists demographic, operative and pathology data on 131 patients (36% women) with a mean ± SD age of 59.8 ± 12.5 years who underwent LPN. Mean ± SD tumor diameter was 2.8 ± 1.2 cm. Median CI was 2.7 (range 0.7 to 9.6). CKD stage was I to V in 45 (34%), 61 (47%), 23 (18%), 2 (1%) and 0 patients preoperatively, and in 12 (9%), 40 (31%), 70 (53%), 9 (7%) and 0 postoperatively, respectively. The mean percent GFR decrease was 28% ± 16%.

Table 2 shows continuous data relationships based on univariate and multivariate analysis. On univariate analysis we noted a positive correlation between logCI and nadir eGFR ($r = 0.29$, $p = 0.002$), and a negative correlation between logCI and the percent decrease in eGFR ($r = 0.4$, $p < 0.001$). Interaction analysis showed no additive or synergistic effect between CI and WIT variables ($p = 0.8$, data not shown). Univariate analysis revealed a positive correlation between tumor diameter and nadir eGFR ($r = 0.25$, $p = 0.007$) and a negative correlation between diameter and the percent decrease in eGFR ($r = -0.27$, $p = 0.004$).

Multivariate regression analysis was done with nadir eGFR and the percent decrease in GFR as independent variables. Nadir eGFR was significantly associated with logCI ($p = 0.008$), WIT ($p < 0.001$) and preoperative eGFR ($p < 0.001$). The total percent decrease in eGFR was significantly associated with logCI ($p = 0.005$) and WIT ($p < 0.001$). Analysis verified no interaction between CI and WIT variables (data not shown). Tumor diameter alone did not correlate with nadir eGFR or the percent decrease in eGFR on multivariate analysis. Preoperative eGFR correlated with nadir eGFR but not

Table 1. *Summary data on 131 patients*

% Rt side	61
Median mg/dl SCr (range):	
Preop	0.9 (0.6–2.9)
Postop	1.4 (0.7–4.1)
Median ml/min/1.73 m^2 eGFR (range):	
Preop	78 (23–148)
Postop	54 (15–127)
Mean ± SE % eGFR decrease	28 ± 13.7
Mean ± SE operative time (mins)	233 ± 81
Mean ± SE WIT (mins)	33.7 ± 9.8