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Original article

Critical appraisal of first-generation renal tumor complexity scoring systems: Creation of a second-generation model of tumor complexity

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Abstract

Objective: To investigate whether a combination of variables from each nephrometry system improves performance. There are 3 first-generation systems that quantify tumor complexity: R.E.N.A.L. nephrometry score (RNS), preoperative aspects and dimensions used for an anatomical (PADUA) classification (PC), and centrality index (CI). Although each has been subjected to validation and comparative analysis, to our knowledge, no work has been done to combine variables from each method to optimize their performance.

Patients and methods: Scores were assigned to each of 276 patients undergoing partial nephrectomy (PN) or radical nephrectomy (RN). Individual components of all 3 systems were evaluated in multivariable logistic regression analysis of surgery type (PN vs. RN) and combined into a "second-generation model."

Results: In multivariable analysis, each scoring system was a significant predictor of PN vs. RN ($P < 0.0001$). Of the first-generation systems, CI was most highly correlated with surgery type (area under the curve [AUC] = 0.91), followed by RNS (AUC = 0.90) and PC (AUC = 0.88). Each individual component of these scoring systems was also a predictor of surgery type ($P < 0.0001$). In a multivariable model incorporating each component individually, 4 were independent predictors of surgery type (each $P < 0.005$): tumor size (RNS and PC), nearness to the collecting system (RNS), location along the lateral rim (PC), and centrality (CI). A novel model in which these 4 variables were rescaled outperformed each first-generation system (AUC = 0.91).

Conclusions: Optimization of first-generation models of renal tumor complexity results in a novel scoring system, which strongly predicts surgery type. This second-generation model should aid comprehension, but future work is still needed to establish the most clinically useful model.

Keywords: R.E.N.A.L. nephrometry score; PADUA classification; Centrality index

1. Introduction

Partial nephrectomy (PN) has emerged as the gold standard for treating small renal masses that are amenable to such an approach [1]. The decision to undergo PN is based on multiple factors but relies heavily on the complexity of the tumor and the clinical gestalt of the surgeon. Multiple systems have been developed to provide a systematic method to quantify tumor complexity. These systems were initially purported to be useful both in the research setting and for assessing tumors in clinical practice, but the extent that they are used in clinical practice remains unclear at present.

R.E.N.A.L. nephrometry score (RNS), preoperative aspects and dimensions used for an anatomical (PADUA) classification (PC), and centrality index (CI) are first-generation scoring systems designed to provide a quantitative assessment of renal tumor complexity [2–4]. These tools were initially designed to enable comparisons of renal masses treated at various institutions and have been shown

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to have significant correlation with clinical practice patterns in both academic and community settings [5,6]. Each system has been individually verified as an acceptable model for predicting a range of variables that are relevant to practicing urologists, including the type of surgery performed (PN vs. radical nephrectomy [RN] or minimally invasive PN vs. open PN) renal tumor pathology, postoperative renal function, and several other outcomes specific to PN [7–15].

To our knowledge, there have been few studies that compared the 3 individual scoring methods in an effort to identify the most significant components of each system [12,16,17]. By analyzing the individual components of each scoring system, we provide a novel perspective on the first-generation models of complexity. We compared all 3 scoring methods on the same group of localized renal tumors treated at our institution. Based on these findings, we integrated the components of each model into a robust predictive model for surgery type. Based on these analyses, we then generated a second-generation complexity score using the most predictive variables.

2. Patients and methods

2.1. Cohort

Institutional review board approval was received for the use of data maintained within our institutional kidney tumor registry. Patients who were younger than 18 years, had locally advanced or metastatic renal cell carcinoma at presentation, had multiple tumors, had a solitary kidney, and who underwent nephrectomy for upper tract urothelial carcinoma or other reasons were excluded from analysis. All patients undergoing a partial or RN for a suspected renal cortical tumor meeting the aforementioned inclusion criteria were included. The cohort included 276 consecutive surgeries by 5 surgeons at a single institution. Surgical management included RN in 151 patients (55%) and PN in 125 patients (45%). Pathologic tumor stage was T1a (66%), T1b (13%), T2 (9%), T3a (11%), and T3b (1%). RNS, PC, and CI scores were assigned based on retrospective review of preoperative cross-sectional imaging (computed tomography or magnetic resonance imaging) for all cases that were included in accordance with published guidelines [2–4]. Scores were assigned for all the cases by a single investigator while blinded to details of the case, including surgeon and surgery type.

RNS has 4 numeric components and 1 descriptive component [2]. PC has 6 numeric components, 2 of which are shared with RNS (size group and exophytic) [3]. CI has 1 numeric component, based on 2 components, which determines the distance of the center of the mass to the center of the kidney [4]. Quantitative variables are expressed as mean and standard deviation (SD). Area under the curve (AUC) is expressed as value and 95% CI.

2.2. Statistical analysis

Statistical analysis was done on the cohort to determine the efficacy of each of the systems at predicting PN vs. RN. Multivariable analysis included the individual components of the 3 scoring systems and was performed to determine the independent predictors of PN vs. RN. Using stepwise assignment of rank, based on the chi-squared values for each of these variables, a novel scoring method was created and tested against the first-generation scoring systems. The DeLong method was used to analyze 4 systems to predict surgery type. The procedure "crossfold," a STATA macro that performs k-fold cross-validation on a specific model, was used to evaluate the optimized model's ability to fit out-of-sample data. All statistical analysis was done using JMP/SAS version 9 and SPSS version 17.

3. Results

Overall, 276 consecutive patients undergoing PN or RN for a localized renal tumor were included. Of them, 151 (55%) and 125 (45%) underwent PN and RN, respectively. Mean age was 61.1 years (SD = 14.2), and 61% were male. Mean glomerular filtration rate was 73.6 (SD = 24.9), and mean tumor size was 4.6 cm (SD = 3.0). Complexity scores (RNS, PC, and CI) were calculated for each tumor, and each individual system was a strong predictor of PN vs. RN (Table 1). Mean RNS scores were 6.03 and 9.24 for PN and RN, respectively ($P < 0.0001$). Mean PC scores were 8.08 and 11.22 ($P < 0.0001$) and

Table 1
Complexity scores and tumor size for tumors treated with PN vs. RN according to 4 scoring systems

	Tumor size Mean ± SD	RENAL Mean ± SD	PADUA Mean ± SD	C index Mean ± SD	Optimized model Mean ± SD
PN	2.86 ± 1.44	6.03 ± 1.59	8.08 ± 1.57	3.40 ± 1.85	5.78 ± 1.44
RN	6.29 ± 3.25	9.24 ± 1.54	11.22 ± 1.74	1.13 ± 0.93	8.54 ± 1.43
P value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
AUC of model for PN vs. RN	0.85	0.90	0.88	0.91	0.91

Each score was strongly correlated with surgery type, as evidenced by $P < 0.0001$. Correlation was assessed by multivariable analysis accounting for age, sex, glomerular filtration rate (GFR), surgeon, and surgery year.