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ORIGINAL ARTICLE

Can Simplified PADUA Renal (SPARE) Nephrometry scoring system help predicting renal function outcomes after robot-assisted partial nephrectomy? (UroCCR study 93)

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ABSTRACT

BACKGROUND: The SPARE Nephrometry Score (NS) is described as easier to implement than the RENAL and PADUA NSs, currently more widely used. Our objective was to compare the accuracy of SPARE NS in predicting renal function outcomes following RAPN.

METHODS: A multicentric retrospective study was conducted using French kidney cancer network (UroCCR, NCT 03293563) database. All patients included had RAPN for cT1 renal tumors between May 2010 and March 2021. SPARE was compared to RENAL, PADUA and Tumor Size to predict postoperative acute kidney injury (AKI), chronic kidney disease (CKD) upstaging, *de novo* CKD at 3-6 months follow-up and Trifecta failure. The ability of the different NSs and tumor size to predict renal function outcomes was evaluated using uni- and multivariate logistic regression models.

RESULTS: According to our study criteria, 1171 patients were included. Mean preoperative tumor size and estimated glomerular filtration rate (eGFR) were 3.4±1.4 cm and 85.8 mL/min/1.73 m^2. In total, 266 (22.7%), 87 (7.4%), 94 (8%), and 624 (53.3%) patients had AKI, *de novo* CKD, CKD upstaging, and Trifecta failure, respectively. In multivariate analysis, all three NSs and tumor size were independent predictors of AKI, CKD *de novo*, CKD upgrade and Trifecta failure. There was no significant difference between all three NS and tumor sizes in predicting renal function outcomes.

CONCLUSIONS: SPARE Score seems to be a valid alternative to predict renal function outcomes after RAPN. Nevertheless, in our study, tumor size was as accurate as NSs in predicting postoperative outcomes and, therefore, seems to be the logical choice for surgical decisions.

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KEY WORDS: Robotic surgical procedures; Nephrectomy; Kidney disease; Kidney neoplasms; Organ dysfunction scores.

Over the last few years, the indications for robot-assisted partial nephrectomy (RAPN) have increased, and it has become the gold standard for the management of small localized (cT1a-b) renal tumors.[1, 2] At the same time, various nephrometry scoring systems (NSs) have been developed to evaluate tumor complexity and therefore facilitate surgical decision making.[3]

RENAL (Radius [R], exophytic/endophytic [E], nearness to collecting system/sinus [N], anterior/posterior [A], and location relative to polar line [L]) and PADUA (Preoperative Aspects and Dimension Used for an Anatomical classification) respectively described in 2009 by Kutikov *et al.*[4] and by Ficarra *et al.*[5] are the two most commonly used nephrometry scoring systems and are recommended by EAU guidelines.[1] However, these methods have limitations, such as poor inter-observer reproducibility, incomplete quantification of relevant anatomical features, and variable correlation with perioperative outcomes.[6]

To simplify and improve NSs, Ficarra *et al.* recently introduced a new Simplified PADUA Renal (SPARE) scoring system to predict the risk of postoperative complications.[6] In contrast to PADUA, this new score includes only four features: rim location, renal sinus involvement, exophytic rate, and maximal tumor size.

The accuracy of the SPARE system in predicting perioperative complications after partial nephrectomy (PN) compared to the RENAL and PADUA scores has already been studied in several external validation studies,[7-11] but only a few studies have specifically investigated its accuracy in predicting functional outcomes after PN.[12]

This study aimed to evaluate the accuracy of SPARE NS in predicting functional outcomes after RAPN and the success of surgery in a French multi-institutional population.

Materials and methods

Study design

All patients included in this study were prospectively enrolled in the French Kidney Cancer Network multicenter database UroCCR (NCT 03293563). After approval from the review board, we conducted a retrospective analysis of all patients who underwent RAPN for cT1a-b stage tumors according to the TNM classification[13] between May 2010 and March 2021. Patients with multiple renal tumors, metastatic disease, those who received neoadjuvant or adjuvant treatment, and those with missing data were excluded.

To define tumors anatomical characteristics, either enhanced abdominal computed tomography (CT) or magnetic resonance imaging (MRI) were performed. Each surgeon prospectively reviewed radiological images to collect each variable of PADUA, RENAL and SPARE NSs according to the original studies. All NSs were categorized as follow: PADUA Low: 6-7, Intermediate: 8-9 and High: ≥ 10; RENAL Low: 4-6, Intermediate: 7-9 and High: 10-12; SPARE Low: 0-3, Intermediate: 4-7 and High: 8-10. Choice of surgical approach and clamping technique was at the surgeon's discretion. Renal function was evaluated using estimated Glomerular Filtration Rate (eGFR) according to Modification of Diet in Renal Disease (MDRD) formula.

In our study, surgery's success was assessed using Trifecta achievement. Trifecta was defined by the combination of negative surgical margins, absence of perioperative complications, and 90% preservation of eGFR at first postoperative follow-up (3-6 months).[14]

Study endpoints

The primary endpoint of our study was to evaluate and compare the accuracy of SPARE NS (*vs.* RE-

NAL, PADUA and Tumor Size) to predict postoperative renal function. It was assessed using:

• acute kidney injury (AKI) according to Risk/Injury/Failure/Loss/End-stage (RIFLE) Classification defined as eGFR loss ≥25% at postoperative day one;

• chronic kidney disease (CKD) upstaging (according to CKD classification) at 3-6 months follow-up after surgery;

• *de novo* CKD at 3-6 months follow-up after surgery.

Our secondary endpoint was to evaluate and compare the accuracy of SPARE NS (vs RENAL, PADUA and Tumor size) to predict Trifecta failure.

Statistical analysis

Data analysis was performed using R software environment for statistical computing and graphics (version 4.0.0) software. The significance level was set at 0.05 for all statistical tests and P values were two sided. Continuous variables were reported as mean and standard deviation (SD) whereas categorical variables were reported as frequencies and proportions.

Predictive factors for AKI at postoperative day one, CKD upstaging and *de novo* CKD at 3-6 months follow-up after surgery and Trifecta failure, were identified through univariate and multivariate logistic regression (adjusted for age, BMI, preoperative eGFR and ASA Score as forced variable to represent patients' comorbidities).

The linearity between the response variable and every continuous variable (age, preoperative eGFR and BMI) was tested for each predictive model using Box-Tidwell Test.

The goodness of fit of each logistic regression model was tested using the Hosmer-Lemeshow Test. The area under receiver operator characteristic (ROC) curve was used to determine accuracy of each NSs (RENAL, PADUA and SPARE) and tumor size. ROC curves were compared using the DeLong Test.

Results

Baseline characteristics of the study population and postoperative outcomes

According to our study criteria, a total of 1171 patients were included. Baseline characteristics of overall cohort are depicted in Table I. The mean age was 59.5 (±12.1), BMI was 27.2 (±5.3), preoperative eGFR was 85.8 (±21.6) and mean tumor size was 3.4 cm (±1.4). The median PADUA, RENAL and SPARE score were 8 [7-10], 7 [6-9] and 3 [1-5] respectively. Mean operative time was 155.1 minutes (±63.9), estimated blood-loss was 234.3 mL (±282.2) and warm ischemic time (WIT) was 14.7 minutes (±11.1) (Table II). Concerning clamping strategy, respectively 190 (16.2%) and 218 (18.6%), selective and off-clamp techniques were performed. Mean postoperative length of stay (LOS) was 3.1 days (±2.8) with an overall complication rate of 15.3% (N.=179). Thirty-one (2.6%) patients had major complication (Clavien-Dindo >2) (Table II). The median follow-up of our cohort was 15.5 [4,6 - 32,9] months.

TABLE I.—*Demographic, clinical and radiological baseline characteristics of our cohort, UroCCR, France 2022 (N.=1171).*

Characteristic	Total (N.=1171)
Demographic and clinical	
Gender, N. (%)	
Male	791 (67.5%)
Female	380 (32.5%)
Age *	59.5 (±12.1)
BMI (kg/m²) *	27.2 (±5.3)
ASA Score*	1.9 (±0.7)
Preoperative eGFR (mL/min/1.73 m²) *	85.8 (±21.6)
Solitary kidney	52 (4.4%)
Side, N. (%)	
Right	600 (51.2%)
Left	571 (48.8%)
Preoperative tumor size (cm)	3.4 (±1.4)
cT stage, N. (%)	
cT1a	825 (70,5%)
cT1b	346 (29.5%)
Nephrometry Scores	
PADUA Score Categories	
Low	382 (32.6%)
Intermediate	420 (35.9%)
High	369 (31.5%)
RENAL Score Categories	
Low	458 (39.1%)
Intermediate	564 (48.2%)
High	149 (12.7%)
SPARE Score Categories	
Low	630 (53.8%)
Intermediate	475 (40.6%)
High	66 (5.6%)

*mean (±SD). PADUA Low: 6-7, Intermediate: 8-9 and High: ≥ 10; RENAL Low: 4-6, Intermediate: 7-9 and High: 10-12; SPARE Low: 0-3, Intermediate: 4-7 and High: 8-10.

TABLE II.—*Intra- and postoperative outcomes of our cohort, UroCCR, France 2022 (N.=1171).*

Characteristic	Total (N.=1171)
Intra and postoperative outcomes	
Surgical approach, N. (%)	
Transperitoneal	1088 (92.9%)
Retroperitoneal	83 (7.1%)
Clamping technique, N. (%)	
Off-clamp	218 (18.6%)
Selective clamping	191 (16.2%)
Arterial	740 (63.2%)
Pedicle mass	22 (1.9%)
WIT (min)*	14.7 (±11.1)
Operative time*	155.1 (±63.9)
EBL (mL)*	234.3 (±282.2)
Peroperative complication, N. (%)	53 (4.5%)
Length of stay (days)*	3.1 (±2.8)
Histology results, N. (%)	
Malignant	1022 (87.3%)
Benign	149 (12.7%)
Positive surgical margins, N. (%)	69 (6.3%)
pT stage, N. (%)	
1	1061 (90.6%)
2	10 (0.9%)
3	100 (8.5%)
Overall postoperatives complications, N. (%)	179 (15.3%)
Major (Clavien-Dindo ≥2)	31 (17.3%)
M3 Postoperative eGFR (mL/min/1.73 m²) *	80.2 (±22.4)
AKI, N. (%)	266 (22.7%)
CKD Upgrade, N. (%)	94 (8%)
de novo CKD, N. (%)	87 (7.4%)
Trifecta failure, N. (%)	624 (53.3%)

*mean (±SD)

Within our cohort, respectively 22.7% (N.=266), 7.4% (N.=87) and 8% (N.=94) of patients had AKI at postoperative day one, de novo CKD and CKD upgrade at 3-6 months (Table II).

Multivariate analysis to predict AKI at postoperative day one

Two hundred sixty-six patients (22.7%) had AKI at postoperative day one (Table II). Multivariate logistic regression analysis to predict AKI is described in Table III. All statistically significant variates in univariate analysis (age, pre-operative eGFR, PADUA, RENAL, SPARE and tumor size) were included in multivariate analysis. BMI and ASA score was also included as forced-in covariate as it's associated with impaired post-operative renal function in literature.[15-17]

In multivariate analysis, all three NSs and tumor size were independent predictors.

Multivariate analysis to predict CKD *de novo* and CKD upgrade at 3 months follow-up

Eighty-seven patients (7.4%) had CKD *de novo* and 94 patients (8%) had CKD upstage at 3-6 months follow-up after surgery (Table II). Multivariate logistic regression analysis to predict CKD de novo and CKD upgrade are described in Table III. In multivariate analysis, high PADUA and RENAL scores were predictors of CKD *de novo* and CKD upgrade but there was no statistical difference between patients with intermediate RENAL and PADUA scores and patients with low RENAL and PADUA scores, adjusted for age, BMI and preoperative eGFR. Regarding SPARE Score, there was a statistical difference in patient having intermediate or high score compared to patients having low SPARE Score.

Multivariate analysis to predict Trifecta failure

Six hundred twenty-four patients (53.3%) had Trifecta failure after surgery (Table II). Multivariate logistic regression analysis to predict Trifecta failure is described in Table III. In multivariate analysis, all three NSs and tumor size were independent predictors of trifecta with an increased risk of Trifecta failure for patients with high PADUA, RENAL or SPARE Score, compared to patients with low scores.

The Hosmer-Lemeshow Test indicated good fit for each regression model (P>0.05).

ROC curves for SPARE, RENAL and PADUA scores as well as tumor size are described in Figure 1. There was no evidence of statistical difference between the ROC curves of each score for the models (P>0.05).

Discussion

Over the last decade, several NSs have been introduced with the aim to facilitate surgeons' ability to safely perform nephron-sparing surgery. A recent meta-analysis by Veccia *et al.* evaluated the predictive value of more than ten NSs. They concluded that RENAL and PADUA scores should be considered as the standards models to predict complexity and perioperative outcomes.[3] If these results reinforce their use, their predictive accuracy remains controversial because of low

TABLE III.—*Multivariate logistic regression analysis for predicting AKI (N.=266), CKD upgrade (N.=94),* de novo *CKD (N.=87), at 3 months and Trifecta failure (N.=624), UroCCR, France 2022.*

	Predictive model							
	PADUA Score model		RENAL Score model		SPARE Score model		Tumor size	
	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value	OR (95% CI)	P value
Age*	1.03 [1.02-1.05]	<0.001	1.03 [1.02-1.05]	<0.001	1.02 [1.01-1.05]	<0.001	1.02 [1.01-1.05]	<0.001
BMI*	1.04 [1.01-1.06]	0.02	1.04 [1.01-1.06]	0.02	1.04 [1.01-1.06]	0.03	1.04 [1.01-1.06]	0.02
Preoperative eGFR*	1.02 [1.01-1.03]	<0.001	1.02 [1.01-1.03]	<0.001	1.02 [1.01-1.03]	<0.001	1.02 [1.01-1.03]	<0.001
ASA Score	1.01 [0.80-1.29]	0.9	1.02 [0.81-1.29]	0.8	0.99 [0.79-1.27]	0.9	0.98 [0.78-1.26]	0.9
AKI								
PADUA Score								
Low	Ref.		-	-	-	-	-	-
Intermediate	1.60 [1.10-2.35]	0.01						
High	2.76 [1.91-4.03]	<0.001						
RENAL Score								
Low	-		Ref.	-	-	-	-	-
Intermediate			1.52 [1.09-2.11]	<0.001				
High			3.85 [2.50-5.94]	<0.001				
SPARE Score								
Low	-				Ref.	-		
Intermediate					1.69 [1.25-2.28]	<0.001		
High					3.11 [1.75-5.44]	<0.001		
Tumor size	-	-	-	-	-	-	1.33 [1.20-1.48]	<0.001
CKD upgrade								
PADUA score								
Low				-		-		-
Intermediate	Ref.	-						
High	1.41 [0.77-2.62]	0.27						
	2.61 [1.48-4.74]	0.001						
RENAL Score								
Low	-	-	Ref.	-	-	-	-	-
Intermediate			1.23 [0.74-2.06]	0.42				
High			2.73 [1.45-5.08]	0.001				
SPARE Score								
Low	-	-	-	-	Ref.	-	-	-
Intermediate					1.99 [1.24-3.22]	0.004		
High					4.52 [2.08-9.41]	<0.001		
Tumor size		-		-		-	1.31 [1.12-1.53]	< 0.001
De novo CKD								
PADUA Score								
Low	Ref.	-	-	-	-	-	-	-
Intermediate	1.40 [0.76-2.66]	0.30	-		-		-	
High	2.22 [1.23-4.13]	0.009						
RENAL Score								
Low	-	-	Ref.	-	-	-	-	-
Intermediate			1.19 [0.71-2.03]	0.49				
High			2.33 [1.19-4.48]	0.01				
SPARE Score								
Low	-	-	-	-	Ref.	-	-	-
Intermediate					1.70 [1.02-2.78]	0.03		
High					4.20 [1.89-8.87]	<0.001		
Tumor size	-	-	-	-	-	-	1.23 [1.04-1.45]	0.01
	-		-		-			
Trifecta								
PADUA Score								
Low	Ref.	-						
Intermediate	1.13 [0.85-1.50]	0.4	-	-	-	-	-	-
High	1.70 [1.26-2.29]	<0.001						
RENAL Score								
Low			Ref.	-				
Intermediate	-	-	1.07 [0.83-1.37]	0.6	-	-	-	-
High			2.33 [1.56-3.52]	<0.001				
SPARE Score								
Low					Ref.	-		
Intermediate	-	-	-	-	1.63 [1.27-2.09]	<0.001	-	-
High					1.79 [1.06-3.08]	0.03		
Tumor size	-	-	-	-	-	-	1.19 [1.09-1.29]	0.006

PADUA Low: 6-7, Intermediate: 8-9 and High: ≥ 10; RENAL Low: 4-6, Intermediate: 7-9 and High: 10-12; SPARE Low: 0-3, Intermediate: 4-7 and High: 8-10.

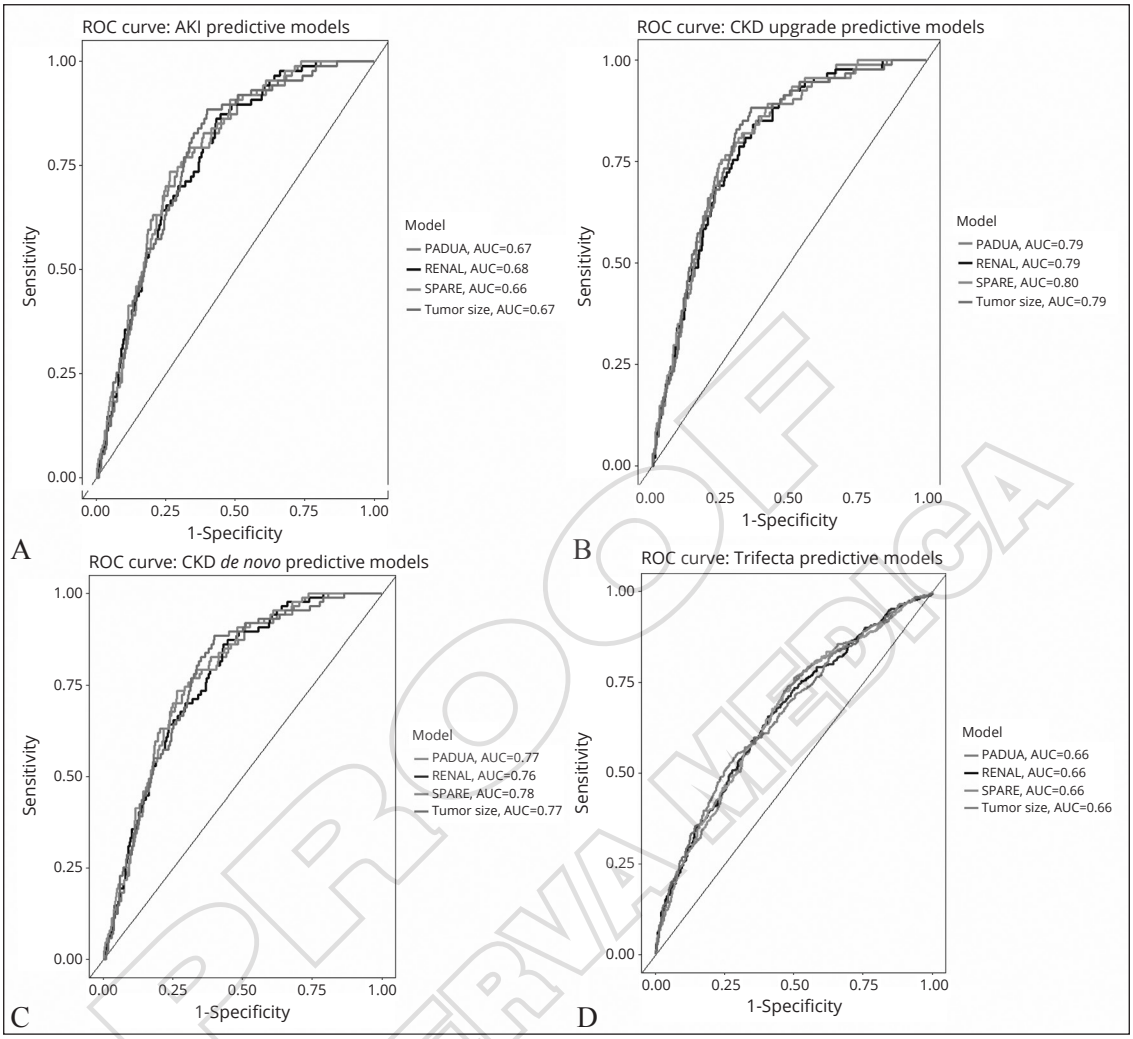

Figure 1.—ROC curves of the three nephrometry scores (PADUA, RENAL, SPARE) and Tumor size for the AKI (A), CKD upgrade (B), *de novo* CKD (C) and Trifecta failure (D) predictive models.

inter-observer reproducibility, incomplete quantification of relevant anatomical features, and variable correlation with peri-operative outcomes.

The SPARE Score was introduced by Ficarra *et al.* to simplify and improve NSs reproducibility.[6]

In comparison to RENAL and PADUA scores, the accuracy of SPARE system to predict perioperative outcomes in patients undergoing PN has already been studied in several external validation studies.[7-10] It seems to be an easy and reproducible tool with a good accuracy to predict perioperative outcomes. Indeed, Weprin *et al.* reported that SPARE score can predict overall complications after RAPN with a similar accuracy than RENAL and PADUA.[7] Same results are found in Huang *et al.* and Diana *et al.* studies, SPARE was as accurate as RENAL and PADUA to predict perioperative outcomes.[8, 9]

Results of our study are consistent with the literature. Indeed, the accuracy of SPARE to predict Trifecta, as described by Hung *et al.*, was comparable to that of RENAL or PADUA (AUC: 0.607 *vs.* 0.622 *vs.* 0.623).

Renal function after PN is difficult to predict as it is influenced by several modifiable and non-modifiable variables[18] and the results differ from one study to another. Some studies suggest that postoperative AKI could be associated with CKD at

long term follow-up.[19] Weprin *et al.*[7] concluded to the absence of association between SPARE Score and postoperative AKI (P=0.7) while Rosiello *et al.*[12] found that patients with intermediate or high SPARE score had increased risk of postoperative AKI (OR 1.84 [1.01-3.37], P=0.04 and OR 2.89 [1.35-6.14], P<0.01). Nevertheless, their results relied on data from a single center and couldn't be generalized to global population. In our multicenter study, intermediate and high SPARE scores were associated with AKI at postoperative day one (OR 1.73 [1.29-2.32], (P<0.001) and 2.92 [1.66-5.08], P<0.001) as well as with CKD upstaging and CKD *de novo* at 3-6 months.

Our study therefore confirms that SPARE Score is predictive of trifecta failure, AKI at postoperative day one, *de novo* CKD and CKD upstage at 3-6 months. While these results are comparable to those of RENAL and PADUA scores, tumor size performed just as good. These findings are consistent with those of Khene *et al.*[10] who established that tumor size alone did as well as NSs in the prediction of major complications after RAPN in a large multicentric European cohort. Furthermore, it also corroborates previously published studies which suggested an association between pre-operative tumor size and renal function impairment after PN.[15, 20, 21]

Machine learning analyses large databases to make more accurate predictions than traditional statistical tools. This technique is increasingly used in many medical fields.[22-24] In urology, several machine learning scores have been developed to accurately predict clinical outcomes such as pT3a upstaging risk of a kidney lesion[25] or progression-free survival after kidney cancer surgery.[26] Lazebnik *et al.*[27] developed a machine learning score to predict the risk of AKI after open PN. However, only one ML algorithm was tested to develop this score and no external validation was performed. It would therefore be interesting to use machine learning on our multicenter cohort to predict renal function after RAPN with better accuracy.

Strengths and limitations of the study

The strength of our study is its large sample size of patients from 18 French institutions with variable surgeon's experience.

However, some limits remain. Although the data were prospectively collected in the UroCCR database, the analyze is retrospective. Then, patients' scans were reviewed in each center without any centralized reassessment. Furthermore, despite the high number of institutions included in our study, variable levels of surgeon's expertise can have impact perioperative outcomes. Finally, as shown in the results, SPARE Score seems to be more discriminative in predicting CKD *de novo* and upgrade. However, there is no statistical difference when comparing the predictive value of the different scores, possibly because of the low number of events (N.=87 and N.=94 respectively).

Conclusions

SPARE appears to be a valid alternative to PADUA and RENAL scores to predict renal function outcomes in patient undergoing RAPN. Nevertheless, in this large multicentric cohort, tumor size was as accurate as NSs to predict postoperative outcomes. As it is simple and replicable, it should be the standard of choice for surgical decisions.

References

1. Ljungberg B, Albiges L, Abu-Ghanem Y, Bensalah K, Dabestani S, Fernández-Pello S, *et al.* European Association of Urology Guidelines on Renal Cell Carcinoma: The 2019 Update. Eur Urol 2019;75:799–810.

2. Casale P, Lughezzani G, Buffi N, Larcher A, Porter J, Mottrie A; ERUS Scientific Working Group. Evolution of Robot-assisted Partial Nephrectomy: Techniques and Outcomes from the Transatlantic Robotic Nephron-sparing Surgery Study Group. Eur Urol 2019;76:222–7.

3. Veccia A, Antonelli A, Uzzo RG, Novara G, Kutikov A, Ficarra V, *et al.* Predictive Value of Nephrometry Scores in Nephron-sparing Surgery: A Systematic Review and Meta-analysis. Eur Urol Focus 2020;6:490–504.

4. Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol 2009;182:844–53.

5. Ficarra V, Novara G, Secco S, Macchi V, Porzionato A, De Caro R, *et al.* Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 2009;56:786–93.

6. Ficarra V, Porpiglia F, Crestani A, Minervini A, Antonelli A, Longo N, *et al.* The Simplified PADUA REnal (SPARE) nephrometry system: a novel classification of parenchymal renal tumours suitable for partial nephrectomy. BJU Int 2019;124:621–8.

7. Weprin S, Falagario U, Veccia A, Nandanan N, Emerson D, Ovanez C, *et al.* Simplified PADUA Renal (SPARE) Neph-

rometry Scoring System: External Validation, Interobserver Variability, and Comparison with RENAL and PADUA in a Single-center Robotic Partial Nephrectomy Series. Eur Urol Focus 2021;7:591–7.

8. Diana P, Lughezzani G, Uleri A, Casale P, Saita A, Hurle R, *et al.* Multi-institutional Retrospective Validation and Comparison of the Simplified PADUA REnal Nephrometry System for the Prediction of Surgical Success of Robot-assisted Partial Nephrectomy. Eur Urol Focus 2021;7:1100–6.

9. Huang CP, Chang CH, Wu HC, Yang CR, Hsieh PF, Chen GH, *et al.* External validation of the Simplified PADUA REnal (SPARE) nephrometry system in predicting surgical outcomes after partial nephrectomy. BMC Urol 2020;20:146.

10. Khene ZE, Mazouin C, Larcher A, Peyronnet B, Gasmi A, Roumiguié M, *et al.* Predicting Complications After Robotic Partial Nephrectomy: back to Simplicity. Eur Urol Focus 2022;8:777–83.

11. Sharma G, Tyagi S, Mavuduru R, Bora GS, Sharma AP, Devana SK, *et al.* External validation of SPARE nephrometery score in predicting overall complications, trifecta and pentafecta outcomes following robot-assisted partial nephrectomy. Minerva Urol Nephrol 2022;74:63–71.

12. Rosiello G, Piazza P, Puliatti S, Mazzone E, Amato M, Tames V, *et al.* Simplified PADUA renal (SPARE) nephrometry score validation and long-term outcomes after robot-assisted partial nephrectomy. Seminars and Original Investigations. 2022;40:65.

13. Amin MB, Greene FL, Edge SB, Compton CC, Gershenwald JE, Brookland RK, *et al.* The Eighth Edition AJCC Cancer Staging Manual: continuing to build a bridge from a population-based to a more "personalized" approach to cancer staging. CA Cancer J Clin 2017;67:93–9.

14. Hung AJ, Cai J, Simmons MN, Gill IS. "Trifecta" in partial nephrectomy. J Urol 2013;189:36–42.

15. Jimenez-Romero ME, Moreno-Cortes JC, Canelon-Castillo EY, Diez-Farto S, Santotoribio JD. Predictive Factors of Renal Function in Partial Laparoscopic Nephrectomy in Patients with a Kidney Tumor. Curr Urol 2019;13:150–6.

16. Winer AG, Zabor EC, Vacchio MJ, Hakimi AA, Russo P, Coleman JA, *et al.* The Effect of Patient and Surgical Characteristics on Renal Function After Partial Nephrectomy. Clin Genitourin Cancer 2018;16:191–6.

17. Sorbellini M, Kattan MW, Snyder ME, Hakimi AA, Sarasohn DM, Russo P. Prognostic nomogram for renal insufficiency after radical or partial nephrectomy. J Urol 2006;176:472–6, discussion 476.

18. Crocerossa F, Fiori C, Capitanio U, Minervini A, Carbonara U, Pandolfo SD, *et al.* Estimated Glomerular Filtration Rate Decline at 1 Year After Minimally Invasive Partial Nephrectomy: A Multimodel Comparison of Predictors. Eur Urol Open Sci 2022;38:52–9.

19. Yang X, Zhang T, Zhou H, Ni Z, Wang Q, Wu J, *et al.* Acute kidney injury as an independent predicting factor for stage 3 or higher chronic kidney disease after nephrectomy. Urol Oncol 2023;41:149.e1–9.

20. Cha EK, Ng CK, Jeun B, Dunning A, Reifsnyder JE, DiPietro JR, *et al.* Preoperative radiographic parameters predict long-term renal impairment following partial nephrectomy. World J Urol 2013;31:817–22.

21. Lane BR, Babineau DC, Poggio ED, Weight CJ, Larson BT, Gill IS, *et al.* Factors predicting renal functional outcome after partial nephrectomy. J Urol 2008;180:2363–8, discussion 2368–9.

22. Bora A, Balasubramanian S, Babenko B, Virmani S, Venugopalan S, Mitani A, *et al.* Predicting the risk of developing diabetic retinopathy using deep learning. Lancet Digit Health 2021;3:e10–9.

23. Tran KA, Kondrashova O, Bradley A, Williams ED, Pearson JV, Waddell N. Deep learning in cancer diagnosis, prognosis and treatment selection. Genome Med 2021;13:152.

24. Bogunovic H, Waldstein SM, Schlegl T, Langs G, Sadeghipour A, Liu X, *et al.* Prediction of Anti-VEGF Treatment Requirements in Neovascular AMD Using a Machine Learning Approach. Invest Ophthalmol Vis Sci 2017;58:3240–8.

25. Boulenger de Hauteclocque A, Ferrer L, Ambrosetti D, Ricard S, Bigot P, Bensalah K, *et al.* Machine-learning approach for prediction of pT3a upstaging and outcomes of localized renal cell carcinoma (UroCCR-15). BJU Int 2023;132:160–9.

26. Khene ZE, Bigot P, Doumerc N, Ouzaid I, Boissier R, Nouhaud FX, *et al.*; Collaborators. Application of Machine Learning Models to Predict Recurrence After Surgical Resection of Nonmetastatic Renal Cell Carcinoma. Eur Urol Oncol 2023;6:323–30.

27. Lazebnik T, Bahouth Z, Bunimovich-Mendrazitsky S, Halachmi S. Predicting acute kidney injury following open partial nephrectomy treatment using SAT-pruned explainable machine learning model. BMC Med Inform Decis Mak 2022;22:133.

Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

Authors' contributions

Clément Klein, Gaëlle Margue and Jean-Christophe Bernhard have given substantial contributions to the conception or the design of the manuscript; Clément Klein, Gaelle Margue, Cécile Champy, Bastien Parier, Thibaut Waeckel, Karim Bensalah, Jonathan Olivier, Nicolas Doumerc, François Audenet, Nicolas Branger, Morgan Roupret, Louis Surlemont, Franck Bruyere, Xavier Durand, Mathieu Durand, Jean-Alexandre Long, Victor Gaillard, Evanguelos Xylinas, Maxime Vallee, Benjamin Rouget, Pierre Bigot, Jean-Christophe Bernhard to acquisition, analysis and interpretation of the data. All authors have participated to drafting the manuscript, Clément Klein and Jean-Christophe Bernhard revised it critically. All authors contributed equally to the manuscript and read and approved the final version of the manuscript.

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