The Predictive Value Of RENAL, PADUA, C-Index, ABC And NePhRO Scores In Minimally Invasive Partial Nephrectomies

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ABSTRACT

Introduction and Objectives: The current study aims to compare the applicability of the RENAL nephrometry score (Radius, Exophytic/Endophytic properties, Nearness to the collecting system or sinus, Anterior/posterior descriptor, and Location relative to the polar lines), the PADUA score (Preoperative Aspects and Dimensions Used for an Anatomical classification), the Centrality Index (C-index), the ABC score, and the NePhRO score in predicting clinical outcomes after minimally invasive partial nephrectomy (MIPN) using laparoscopic and robot-assisted techniques.

Materials and Methods: We searched PubMed and Web of Science to examine the correlation between these nephrometry scores and operative time (OT), warm ischemia time (WIT), estimated blood loss (EBL), absolute change in estimated glomerular filtration rate- eGFR (ACE), length of hospital stay (LOS), as well as postoperative complications, up until September 2024, that were written in English.

Results: A total of 22 studies, including 3,022 patients, met the criteria for further analysis. Overall, all scoring systems showed statistically significant correlations with at least one of the following: OT, WIT, EBL, ACE, and LOS. The C-index had the strongest correlation with ischemia time and ACE. Additionally, the C-index proved to be a better indicator of surgical complications in several studies compared to the other nephrometry scores. The vast majority of studies included in the review focused on analyzing the predictive accuracy of the RENAL and PADUA scores.

Conclusions: We found that all nephrometry scores demonstrated statistically significant correlations with WIT, EBL, OT, and ACE. Moreover, the C-index scoring system is the best predictor of WIT and ACE. The NePhRO and ABC scores require further studies for a more comprehensive and accurate analysis of their predictability.

Key-words: C-index, minimally invasive, PADUA, partial nephrectomies, RENAL

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INTRODUCTION

The morbidity of renal cell carcinoma (RCC) ranks sixth in men and eighth in women among all tumors. However, in clinical practice, the vast majority of RCC patients remain asymptomatic even in the late stages. Due to the widespread application of radiological imaging (e.g., ultrasonography and computed tomography), RCC cases can be detected more frequently. Although there are different types of therapies for RCC at various stages, surgery is the only effective treatment for localized RCC. Thus, radical nephrectomy (RN) and partial nephrectomy (PN) have been successively established. For clinically localized RCC, previous studies have demonstrated that PN is superior to RN due to its advantages in preserving overall kidney function and a lower risk of metabolic and cardiovascular complications[1] [2].

As specified by the European Association of Urology, since 2007, partial nephrectomy has been a sustainable curative approach for the treatment of RCC. For tumors >4–7 cm in maximum diameter (T1b tumors), PN can be performed in specialized centers on selected patients, and open partial nephrectomy (OPN) is currently considered the standard of care, as it provides the same oncological outcomes as radical nephrectomy (RN) but preserves better renal function and quality of life. However, compared to RN, PN is a more challenging procedure for surgeons, especially in complex renal tumors. Therefore, assessing its complexity before PN is of great necessity[2].

Additionally, in recent years, there has been an increasing emphasis on the minimally invasive approach to tumors suitable for PN, both laparoscopically and robotically, with a shift in popularity over the last 10 years in favor of robot-assisted surgeries.

Over the past 15 years, several nephrometry scoring (NS) systems have been proposed to standardize renal masses and aid in surgical strategy decisions. Among these are the RENAL nephrometry score (Radius, Exophytic/Endophytic properties, Nearness to the collecting system or sinus, Anterior/posterior descriptor, and Location relative to the polar lines)[3], the PADUA score (Preoperative Aspects and Dimensions Used for an Anatomical classification)[4], and the Centrality Index (C-index)[5], which are the most well-known and widely used systems globally.

The PADUA score focuses on the anatomical criteria of renal tumors. In their series, Ficarra et al. demonstrated that a detailed consideration of the anatomical factors of the renal tumor in relation to its renal location provided a relatively reliable prediction of postoperative evolution regarding complications, better than considering only the tumor size–[6].

The PADUA score evaluates the clinical size of the tumor and the renal and intrarenal anatomical characteristics of the tumor location (upper, lower, middle, lateral, medial; exophytic or endophytic; infiltration of adjacent structures such as the renal sinus or collecting system). The total PADUA score is then considered predictive of the postoperative course after partial nephrectomy. It has been grouped into three categories [low (6–7), medium (8–9), or high (≥10)] as suggested by the original publication and into two categories [low (<8), high (≥8)]–[6].

The RENAL nephrometry scoring system was developed to classify renal masses into low, intermediate, and high complexity based on imaging results. Its purpose is to assist in decision-making, patient counseling, surgical planning, patient follow-up, and academic reporting. It takes into account: maximum diameter (radius), exophytic/endophytic location, distance from the collecting system, anterior/posterior location, inferior/superior location, and additionally adds the prefix "h" if the tumor mass comes into contact with the main renal vein or artery. The results obtained correlate with case complexity: score 4-6: low; score 7-9: moderate; score 10-12: high complexity[7].

The ABC scoring system was proposed in 2016 as a new anatomical evaluation tool developed to help understand the complexity of renal masses and

predict the outcomes of kidney surgery. Specifically, the ABC score refers to the depth of renal tumors and the size of the renal arterial branches that are to be sectioned during PN"[8].

The C-index score is a continuous variable that describes the geometric relationship between the tumor and the kidney, which is based on the ratio between the distance from the center of the tumor to the center of the kidney (c) and the radius of the tumor (r): c/r. The C-index can be measured using standard 2D CT images. A score of 0 equates to a tumor that is concentric with the center of the kidney; a score of 1 equates to a tumor that touches the center of the kidney with its peripheral zone. As the centrality index increases, the tumor periphery becomes more distant from the center of the kidney[5].

The NePhRO scoring system is based on four components related to tumor characteristics and kidney anatomy. It divides the kidney and masses into anatomical zones, avoiding numbers, letters, and lines that can lead to observer-dependent variations. The NePhRO components are related to the anatomical zones of the kidneys (proximity to the collecting system, location relative to the renal pole, diameter, exophytic/endophytic), which aid in classification. Each component is scored from one to three. After the four components have been defined, the individual scores are established and summed. The final score indicates whether a mass is of low, intermediate, or high complexity. Specifically, it stratifies the risk as low (4-6 points), moderate (7-9 points), and high (10-12 points)[9].
Although many studies have been published to validate the correlation between these NS and clinical outcomes, it remains controversial which scoring system could most accurately evaluate these outcomes. Therefore, we conducted a systematic review to parallelly compare the role of scoring systems in predicting perioperative and postoperative outcomes of PN.

Inclusion And Exclusion Criteria

Inclusion Criteria: (a) Comparative studies conducted prospectively or retrospectively; (b) patients who underwent minimally invasive PN; (c) patients who were simultaneously evaluated according to renal scores such as RENAL, PADUA, ABC, NePhRO, and C-index; (d) perioperative and postoperative outcomes could be obtained.

Exclusion Criteria: (a) Incomplete or invalid data; (b) no conclusive result; (c) republished reports; (d) review articles and editorial comments; (e) case reports or series.

Study Quality Evaluation

Titles and abstracts of articles that met our inclusion criteria were independently analyzed. Then, a full analysis was performed to ensure inclusion. Extracted data included: year of study, center, type of study, number of patients, type of surgery, types of nephrometry scores used, perioperative and postoperative outcomes.

Evaluated Outcomes

At least one specific perioperative outcome after PN should be included in the study, including operative time (OT), estimated blood loss (EBL), length of hospital stay (LOS), absolute change in estimated glomerular filtration rate (ACE), and warm ischemia time (WIT) – duration of clamping of the renal artery, to be eligible for an objective evaluation of the predictive value of the scores. Among these, WIT is defined as the duration of clamping of the renal artery.

A comprehensive analysis was conducted using the PubMed and Web of Science databases for the following keywords: ([nephrometry] OR [RENAL] AND [PADUA] AND [centrality index] OR [C-index] OR [ABC score] OR [NePhRO]).

RESULTS

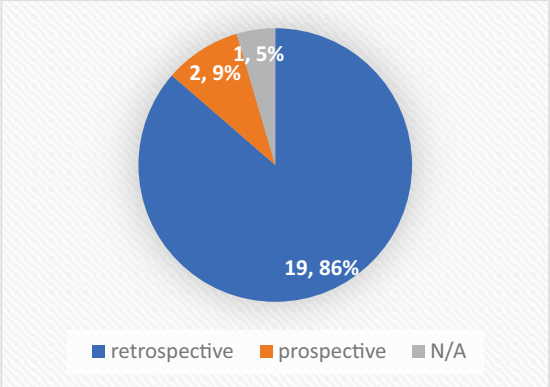
With a total of 3,022 patients, 22 studies published between 2012 and 2024 were included in the review. Nineteen of them were retrospective, two were prospective, and one did not mention the type of research. The patient cohorts in the studies had at least 30 patients to be included in the review, conducted over a minimum period of one year.

The majority of these studies used CT evaluation, and in some, MRI examination was additionally used, while in seven of the studies, the type of imaging used for tumor evaluation was not mentioned.

In 15 of the studies, were performed robotic surgeries and in the remaining seven, both robotic and laparoscopic surgeries were performed.

Study	Year of publication	Number of patients	Laparoscopic	Robotic	C-index	Padua	RENAL	ABC	NePhRO
J. S. Ellison, et al[10]	2012	298	+	+			+		
J. S. Yeon, et al[11]	2014	113		+		+	+		
J. W. Lee, et al[12]	2014	106		+		+	+		
C. M. Yang, et al[13]	2014	178	+	+		+	+		
K. Ener, et al[14]	2015	42		+		+	+		
S. Ricciardulli, et al[15]	2015	258	+	+		+	+		
K. J. Ko, et al[16]	2015	317	+	+		+	+		
A. Roman, et al[17]	2016	100		+		+	+		
K. Ener, et al[18]	2016	34		+		+	+		
B. P. Rai, et al[19]	2017	78		+	+	+		+	
A. Alenezi, et al[20]	2017	60		+		+			
R. M. Kumar, et al[21]	2017	104	+	+	+	+			+
R. B. Corradi, et al[22]	2017	283		+	+	+			
A. Simsek, et al[23]	2017	42	+	+		+			
R. Schiavina, et al[24]	2017	277		+		+			
A. Porreca, et al[25]	2018	81		+		+	+		
S. Y. Lu, et al[26]	2018	204		+		+	+		
F. Porpiglia, et al[27]	2018	52		+		+			
M. D. Vartolomei, et al[28]	2019	52		+		+			
K. Karamık, et al[29]	2020	78	+	+	+	+	+		
K. Karamık, et al[30]	2021	91		+	+	+	+		
S.Miyamoto, et al[31]	2024	174		+	+	+	+		

Table 1. Type of surgery and nephrometry scores



Cart 1. Type of study

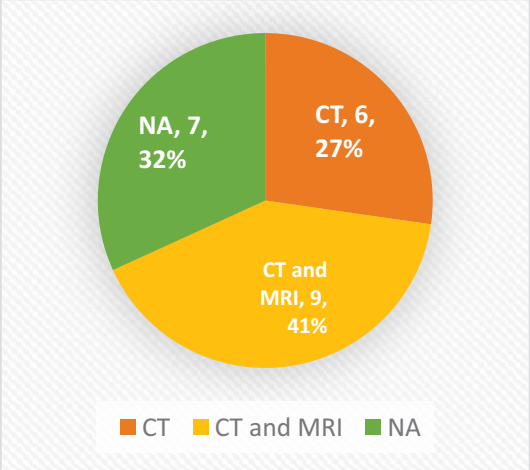


Chart 2. Type of imaging evaluation of kidney tumor

The most used approach was transperitoneal; in one study performed only in retroperitoneal approach, 6 out of the total 22 were both transperitoneal and retroperitoneal, and in one study the type of approach used was not mentioned.

An increased PADUA score is a good predictor of WIT and ACE, without significant impact on EBL, OT, or LOS. PADUA is statistically a significant good predictor score for the general evaluation of surgical complications. Similar data were obtained regarding the RENAL score.

The C-index score is statistically the best predictive factor of WIT and ACE; it was considered the least variable factor regardless of the evaluator, as demonstrated in two of the studies included in the review.

Regarding the NePhRO and ABC scores, there were only two studies included in the review that demonstrated these would have an impact on the predictability of perioperative complications.

DISCUSSION

Current studies have shown contradictory reports. Some studies have demonstrated the correlation of scoring systems with perioperative parameters and postoperative renal functional changes – eGFR, while others have found a weak or even no correlation between each system and outcomes after PN.

Regarding the evaluation of scoring systems exclusively for minimally invasive PN, relatively few studies meet this criteria. The major trend was for open PN due to the complexity of the intervention, being considered the standard of care for patients with this surgical indication. However, in recent times, there is a trend towards the minimally invasive approach, even more so robotically than laparoscopically, as demonstrated by this study.

Therefore, to provide an evidence-based perspective for clinical judgment, the present study integrated studies from the literature that analyze the predictability of these scores in minimally invasive interventions, to demonstrate the correlation between these and perioperative complications, and which evaluation system worked better. The C-index score was the strongest predictor of WIT and ACE, while EBL, OT, and LOS were weakly correlated with all five scores.

CONCLUSION

In conclusion, three evaluation systems were significantly correlated with warm ischemia time, blood loss, operative times, and ACE – PADUA, RENAL and C-index score. Moreover, the C-index score surpassed the RENAL and PADUA scoring systems in predicting WIT and ACE in some studies. The ABC and

NePhRO scores should be further evaluated in minimally invasive PN to have a more accurate expertise of their predictive value.

Study	WIT	ACE	EBL	OT	Over all complications	Nephrometry scores
J. S. Ellison, et al[10]	+	+	+	+	+	RENAL
J. S. Yeon, et al[11]		+				PADUA, RENAL
J. W. Lee, et al[12]	+	+			+	PADUA
C. M. Yang, et al[13]	+	+	+		+	PADUA, RENAL
K. Ener, et al[14]			+			PADUA, RENAL
S. Ricciardulli, et al[15]	+	+			+	PADUA
K. J. Ko, et al[16]	+				+	PADUA
A. Roman, et al[17]		+				PADUA
K. Ener, et al[18]				+	+	PADUA, RENAL
B. P. Rai, et al[19]	+	+		+		C-index, ABC
A. Alenezi, et al[20]	+		+			PADUA
R. M. Kumar, et al[21]	+				+	C-index, PADUA, RENAL
R. B. Corradi, et al[22]	+	+	+		+	C-index, PADUA, RENAL
A. Simsek, et al[23]					+	PADUA, RENAL
R. Schiavina, et al[24]	+				+	PADUA, RENAL
A. Porreca, et al[25]						PADUA, RENAL
S. Y. Lu, et al[26]	+					PADUA, RENAL
F. Porpiglia, et al[27]	+	+				PADUA
M. D. Vartolomei, et al[28]	+	+	+	+	+	PADUA, RENAL
K. Karamık, et al[29]	+	+	+	+	+	C-index, PADUA, RENAL
K. Karamık, et al[30]	+	+				PADUA
S.Miyamoto, et al[31]	+	+	+	+	+	C-index, PADUA, RENAL

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