Original Article

Evaluation of modified RENAL nephrometry score in the prediction of perioperative outcomes of open partial nephrectomy

K. Annappa Kamath*, Vasudevan S. Pothy, Himanshu Pandey

Department of Urology, Government Medical College, Thiruvananthapuram, Kerala, India

*E-mail: kamathannappa@gmail.com

ABSTRACT

Introduction: RENAL nephrometry score (RNS) is a standardized system to grade the complexity of renal masses, but it does not correlate well with the perioperative outcomes of open partial nephrectomy (OPN). To overcome these shortcomings, a modified RNS (MRNS) has been proposed. In this study, we evaluated the MRNS and its role in predicting the perioperative outcomes of OPN.

Methods: This was a prospective observational study performed at a tertiary care hospital to evaluate the efficacy of MRNS in predicting the perioperative outcomes of OPN. Sixty-four cases were included in the study. Demographic parameters, tumor characteristics, and perioperative outcomes were analyzed. Correlation with the post-operative outcomes and the strengths of MRNS were compared with various other nephrometry scores.

Results: The mean age of the patients was 52.89 years, 60.9% were male and 53.1% had a right-sided mass. The comorbidities, body mass index, and performance scores were evenly distributed across the complexity groups ($P > 0.05$). The mean tumor size was 4.13 cm and the mean MRNS and RNS were 9.45 and 6.1, respectively. 60.9% of the cases had no complications. Major complications (Clavien–Dindo grade [CDG] 3+) were noted in five cases (7.8%). The trifecta of neargin, ischemia, and complications (MICs) score was achieved in 85.9% and was achieved in 71.9% of the cases. MRNS was found to be an independent predictor of the trifecta outcomes ($P = 0.04$). Receiver-operating characteristic curve of MRNS analyzing the major complications as per the CDG showed an area under the curve of. 804, indicating good prediction of complications by the MRNS.

Conclusions: MRNS improves the predicting power of RNS by attributing enhanced scores to key elements and by adding new elements. Also, MRNS has good ability to predict the achievement of the trifecta and MIC.

INTRODUCTION

Partial nephrectomy (PN) has become a routine surgical procedure, accounting for about half of all the renal tumor surgeries.[1] Several scoring systems have been described to characterize renal lesions in terms of the feasibility of PN. The RENAL nephrometry score (RNS) is the most often utilized score and the preoperative aspects and dimensions used for an anatomical (PADUA) score and the Centrality Index (C-index) are the two other commonly used scores.[2] Correlation of these scores with the perioperative outcomes of PN is at times equivocal.[3] Salah *et al.*[4] proposed a modification of RNS by incorporating new elements: Hilar score and renal pelvic score (RPS). They also enhanced the score points given to "E" and "N" of the original RNS [Table 1]. We evaluated the utility of this modified RNS (MRNS) in predicting the perioperative outcomes following open PN (OPN) including the achievement of the trifecta and the margin, ischemia, and complications (MICs) score.

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Table 1: Salah *et al.*[4] modified nephrometry score

Feature	1 point	2 points	>2 points
Radius (maximal diameter in cm)	≤4	>4 but <7	≥7 (3 points)
Exophytic nature	≥50%	<50%	Entirely endophytic (5 points)
Nearness to collecting system (mm)	>7	>4 but <7	<4 (4 points)
Anterior/posterior	Mass assigned a descriptor of a, p or x		
Location relative to the polar lines	Entirely above the upper or below the lower polar line	Lesion crosses polar line	>50% of mass is across polar line (a) or mass crosses the axial renal midline (b) or mass is entirely between the polar lines (c) (3 points)
Renal pelvic score percentage of pelvis inside parenchyma	<50% (1 point)	-	≥50% (3 points)
Hilar involvement	No hilar involvement (0 point)		Hilar involvement (5 points)

METHODS

Study design and inclusion criteria

A prospective observational study, to evaluate the utility of MRNS in predicting the perioperative outcomes of patients with renal mass undergoing OPN at a tertiary care hospital, was conducted after obtaining approval from the Institutional Research board Committee and Ethics Committee (HEC/09/12/2021/MCT). All adults who were planned for PN for clinically malignant tumor (up to stage T1N0M0), symptomatic AML and Bosniak type III and IV cysts were included in this study, after written informed consent. Patients with altered anatomy such as congenital anomalies or those with prior renal surgery like PN or percutaneous nephrolithotomy and those who had a PN for stone disease or chronic infection, were excluded. Patients included in the study were explained about the procedure in detail, and queries were addressed with due diligence. Written informed consent was obtained from all the patients. All the procedures were in accordance with the Declaration of Helsinki and its amendments.

Setting

Sixty-four patients who fulfilled the inclusion criteria between June 2021 and November 2022 were evaluated. The demographic parameters, tumor characteristics, and perioperative outcomes were analyzed. Patients were followed up postoperatively for a period of 1 month. Any complications were recorded and the histopathology of the PN specimen was also noted. The said parameters were correlated with the following nephrometry scores - MRNS, RNS, PADUA, Simplified PADUA REnal (SPARE) nephrometry system, NePhRO and C index.

Surgical management and postoperative care

Under general anesthesia, an ipsilateral flank up position with table break and kidney rest was made. An 11th rib cutting incision was adopted for a trans-gerotal approach. Mass was localized intraoperatively by direct visualization or ultrasound guidance. Perinephric fat over the mass was preserved. All the masses were resected in a standard fashion with hilar dissection followed by renal artery only clamp (except for eight cases of exophytic polar masses, which were resected off clamp). The incision line was marked using a cautery, leaving a thin rim of normal parenchyma around the mass. This was then deepened using a combination of blunt and sharp dissection to excise the mass completely. Frozen biopsy was used in two cases with doubtful resection margins (both the cases were converted to radical nephrectomy (RN) as negative margins could not be achieved despite re-resection). Pelvi-calyceal system (PCS), if entered, was repaired with polygalactin 4-0 (six cases). For cases with tumor abutting the PCS (Nearness to PCS < 4mm) preoperative stenting was done. Renorrhaphy was performed in two layers using interrupted absorbable 2/0 sutures with absorbable gelatin pledgets. Hemostasis was ensured and a drain was kept in the retroperitoneum prior to the closure. Once the drain and the urethral catheter were removed, the patient was discharged on the postoperative day 3 or 4. Follow-up visits were scheduled at 1st week and 4th week. At each visit, serum creatinine was obtained (postoperative estimated glomerular-filtration rate [eGFR] calculated at 4th week) and office ultrasound was performed to rule out collections/urinoma.

Variables and data collection

Demographic parameters, tumor characteristics, and various nephrometry scores were recorded. Perioperative outcomes such as ischemia time, operative time, estimated blood loss, blood transfusion, PCS entry, conversion to RN, urinary leakage, length of hospital stay, postoperative renal function, and pathology findings were also recorded. Standardized outcome measurement using the Trifecta and MIC score was undertaken. Trifecta[5] outcomes include simultaneous realization of three key outcomes: negative cancer margins, minimal renal functional decline, and no urological complications (Clavien–Dindo grade [CDG] 0–2). Whereas the MICs score[6] is realized when (1) surgical margins are negative, (2) WIT is <20 min, and (3) no major complications (CDG 3/4) are observed. Data recording did not involve the operating team. The complete data are available for access on request.

Statistical methods

The data were entered into an Excel sheet and analyzed using the SPSS version 25.0. Quantitative variables such as preoperative hemoglobin (Hb), postoperative Hb, preoperative eGFR, postoperative eGFR (4th week) and renal nephrometry

scores (MRNS, RNS) were summarized as mean and standard deviation. Qualitative variables such as complexity of the mass and the complication rate were expressed as frequency, percentage, and 95% confidence intervals.

Based on the complexity group, postoperative parameters including the complications were compared to evaluate the role of MRNS in predicting the perioperative outcomes of OPN. For normally distributed data, the means of complexity groups (low, intermediate, and high) were compared using the one-way ANOVA followed by *post hoc* multiple comparisons test. For skewed data, Kruskal–Wallis test was used followed by Mann–Whitney *U*-test for two groups. To compare the two groups for normally distributed data, Student's *t*-test was applied. Proportions were compared using the Chi-square or Fisher's exact test, depending on their applicability for two groups. Spearman or Pearson correlation coefficients were calculated to see the relationship of different variables. $P < 0.05$ was considered statistically significant.

RESULTS

Demographic and perioperative data

Sixty-four cases were included in this study and the mean age of the patients was 52.89 ± 2.7 years and 60.9% were males. The mass was on the right side in 53.1% (34/64) and hypertension (35.9%) and diabetes mellitus (31.3%) were the most common comorbidities. Mean body mass index was 23.1 and the performance index was generally good [Table 2].

Characteristics of renal mass

On analyzing the characteristics of the renal mass [Table 2], the size of the mass ranged between 4 and 7 cm in 54.7% and the mean diameter was 4.13 cm. Most of the masses were >50% exophytic (53.1%), 60.9% of them were >7 mm away from the PCS and 54.7% were entirely above the upper or below the lower polar line. Hilar involvement was absent in 90% and the renal sinus fat was not involved in 93.8%. A lateral rim was observed in 79.7% and most of them had no perinephric fat stranding (98.4%). Complexity as per the MRNS was low (5–9) in 65.6%, moderate (10–14) in 25%, and high (15–23) in 9.4% of the renal masses. Meanwhile, the complexity as per the RNS was low (4–6) in 65.6%, moderate (7–9) in 28.1%, and high (10–12) in 6.3% of the cases. The mean MRNS and RNS were 9.45 and 6.1, respectively. Other scores are depicted in Table 2.

Perioperative parameters

The mean operative time was 2.48 h and the mean blood loss was 310 mL with a mean hemoglobin drop of 0.63 g/dL. The mean eGFR drop was 12.36 mL/min/1.73 m^2 and the mean duration of hospital stay was 3.9 days. No complications were observed in 60.9% of the cases [Table 3] and the most frequent complication was the need for transfusion (08) followed by postoperative fever (05), SSI (04), urinoma (03), noninvasive ventilation (NIV) support (02), and paralytic ileus (02). Major complications (CDG 3+) were noted in five cases (7.8%) - Urinoma (3) and NIV support (2). The NIV support was required in two cases with multiple comorbidities and we feel this should not be attributed to the complexity

Table 2: Preoperative variables

Demographic parameters	*n* (%)
Age (years)	
18–37	8 (12.5)
38–57	29 (45.3)
58–77	27 (42.2)
Gender	
Male	39 (60.9)
Female	25 (39.1)
Renal mass	
Left	30 (46.9)
Right	34 (53.1)
BMI (kg/m^2)	
Normal (18.5–23)	29 (45.3)
ECOG (0)	31 (48.4)
ASA (2)	33 (51.6)
Characteristics of renal mass	***n* (%)**
Radius (maximum diameter) (cm)	
<4	29 (45.3)
4–7	35 (54.7)
Phytic	
>50% exophytic	34 (53.1)
>50% endophytic	25 (39.1)
Completely endophytic	5 (7.8)
PCS nearness (mm)	
>7	39 (60.9)
4–7	20 (31.3)
<4	5 (7.8)
Location with respect to polar lines	
Entirely above the upper or below the lower polar line	35 (54.7)
Lesion crosses polar line	24 (37.5)
>50% of mass is across polar line	5 (7.8)

Tumor complexity based on NS

NS	Complexity	Score	Frequency (%)	Mean
MRNS	Low	5–9	42 (65.6)	9.45
	Moderate	10–14	16 (25)	
	High	15–23	6 (9.4)	
RNS	Low	4–6	42 (65.6)	6.1
	Moderate	7–9	18 (28.1)	
	High	10–12	4 (6.3)	
PADUA	Low	6–7	33 (51.6)	7.83
	Moderate	8–9	21 (32.8)	
	High	10+	10 (15.6)	
SPARE	Low	0–3	51 (79.7)	2.61
	Moderate	4–7	11 (17.2)	
	High	8–11	2 (3.1)	
NePhRO	Low	4–6	16 (25)	7.3
	Moderate	7–9	44 (69)	
	High	10–12	4 (6)	
C index	Low	>2	19 (30)	1.81
	Moderate	1–2	29 (45)	
	High	1–1.5	16 (25)	

NS=Nephrometry score, BMI=Body mass index, ECOG=Eastern cooperative oncology group, ASA=American Society Of Anesthesiologists, MRNS=Modified renal NS, RNS=Renal nephrometry score, PADUA=Preoperative aspects and dimensions used for an anatomical score, SPARE=Simplified PADUA renal score, PCS=Pelvi-calyceal system

Table 3: Outcome variables

A	**Peri-operative characteristics**		**Mean±SD**	
	Operative time (h)		2.48±0.66	
	Blood loss (mL)		310.16±114.49	
	Hb drop (g/dL)		0.63±0.807	
	GFR drop (mL/min/1.73 m^2)		12.36±17.26	
	Hospital stay (days)		3.91±1.377	
B	**Histopathology**		**Frequency (%)**	
	Clear cell carcinoma		44 (68.8)	
	Chromophobe carcinoma		2 (3.1)	
	Papillary carcinoma		4 (6.3)	
	Oncocytoma		1 (1.6)	
	Tuberculosis		2 (3.1)	
	Complex cyst		6 (9.4)	
	Angiomyolipoma		3 (4.7)	
	Benign		2 (3.1)	
C	**Complications**		**Frequency (%)**	
	Absent		39 (60.9)	
	Present		25 (40.1)	
D	**CDG**		**Frequency (%)**	
	Absent		39 (60.9)	
	Grade 1		8 (12.5)	
	Grade 2		12 (18.8)	
	Grade 3A		1 (1.6)	
	Grade 3B		2 (3.1)	
	Grade 4A		2 (3.1)	
E	**NS v/s Trifecta**	**Mean score of Trifecta achieved**	**Mean score of Trifecta failed**	***P***
	RNS	5.8	6.5	0.28
	MRNS	8.9	10.5	0.04
	PADUA	7.6	8.2	0.19
	SPARE	2.34	3	0.11
	NePhRO	7	7.7	0.14
	C index	1.90	1.66	0.06
	Percentage	71.9	28.1	

Hb=Hemoglobin, GFR=Glomerular filtration rate, MRNS=Modified renal nephrometry score, RNS=Renal nephrometry score, PADUA=Preoperative aspects and dimensions used for an anatomical score, SPARE=Simplified PADUA renal score, CDG=Clavien–Dindo grade, SD=Standard deviation

of the mass or towards the surgical complication. The PCS was entered in six cases (9.4%) and a meticulous repair was performed with Vicryl 4-0 suture in all of these cases. Among these, five cases were pre-stented and the patient who was not prestented developed post-operative urinoma and was managed by postoperative stenting on POD5. Two cases required conversion to RN as tumor free margins could not be achieved due to the proximity of the mass to the hilum. Most common histopathology was malignancy in 78.1% of the cases (clear cell carcinoma - 68.8%) followed by benign cysts (12.5%). Two cases had positive margin at the final histopathology and were placed under strict surveillance as the margins were only focally positive. The MICs score was achieved in 85.9% of the cases and the Trifecta was achieved in 71.9% cases.

Effect of Modified RENAL nephrometry score complexity on the outcome

On correlating the complications with the MRNS, the lesions with low complexity were more likely to have lower incidence and lower grade of complications as compared to the more complex lesions. Also, the complexity of the renal mass, according to the MRNS, correlated with the CDG of complication ($P < 0.005$). The high complexity group was found to have a greater drop in eGFR, but the statistical significance was not reached ($P = 0.12$). The mean scores among the cases that did not achieve the trifecta were significantly higher than the ones in which the trifecta was achieved (MRNS 10.5 vs. 8.9). Six cases belonged to the high complexity group as per the MRNS system. All the high complexity cases had longer operating time, PCS entry, requirement of blood transfusion and higher mean blood loss (475 mL) ($P < 0.05$). Of these high complexity lesions, two required intra-operative conversion to RN, three cases developed urinoma - two of which were pre-stented. The non pre-stented case had a RNS of 9 and MRNS of 16 and although the tumor was away from the PCS, the pelvis was intrarenal and the lesion was endophytic and required postoperative stenting. On the final histopathology, all the six cases showed malignancy and the margins were positive in two patients.

Comparison with other scores

The scatter plot of the nephrometry score versus CDG of complication is depicted in Figure 1. The trendline shows that the scores and the grade of complications have a linear relation, i.e., higher scores tend to have more severe grade of complication. Among these, the slope of MRNS trendline is the highest indicating that the MRNS illustrates a linear relation between the score and complications with highest distinction. Area under the receiver-operating characteristic curve [Figure 2] of RNS and MRNS for CDG v/s score was 0.716 and 0.804, respectively. MRNS has a higher area under the curve, which indicates better prediction of complications than the RNS. All the high complexity tumors, as per the MRNS (15–23), were malignant (6/6) ($P < 0.05$) compared to 4/4 for RNS, 9/10 for PADUA, 2/2 SPARE and 4/4 NePhRO. High complexity group of the MRNS faired better than the others in predicting malignancy. The rate of achieving the trifecta [Table 3] was statistically significant only for the MRNS in our study ($P = 0.04$).

DISCUSSION

MRNS is modified RNS and incorporates new parameters in the score such as the hilar involvement and RPS and has increased the score points ascribed to *"E"* and *"N"* of the original RNS. The rationale for the same is the independent predictive power of E and N. Liu *et al.* found "N" to be associated with both the incidence of complications and postoperative bleeding.[7] Bruner *et al.*[8] found that among the components of R.E.N.A.L, the "E" score was a significant predictor of postoperative urine leak. According to Tomaszewski *et al.*,[9] the "E" score has a high independent correlation with urine leak while the overall NS and its other components do not. Tomaszewski *et al.*[10] in their internal validation of RPS and Veccia *et al.*[3] in their meta-analysis

showed that the RPS offered a better predictive value for PCS entry/repair and urine leak. Hilar involvement, described as mass abutting the renal artery or vein, also affects the complexity of surgery.[4] We prospectively evaluated 64 patients undergoing OPN to evaluate the efficacy of modified scoring system.

The demographic and renal mass characteristics of our study mirrored that of several other studies and were similar among the complexity groups. In the studies reported by Gupta *et al.*[11] and Ketsuwan *et al.*[12] the majority of the resected lesions were of malignant histology, 89.0% and 87%, respectively, and the mean diameter of the renal mass was 2.7 cm (Range 1.8–3.8) and 4.25 cm (range 1.1–7 cm), respectively. The pilot study by Salah *et al.*[4] that evaluated MRNS had a mean RNS of 9 and MRNS of 12.

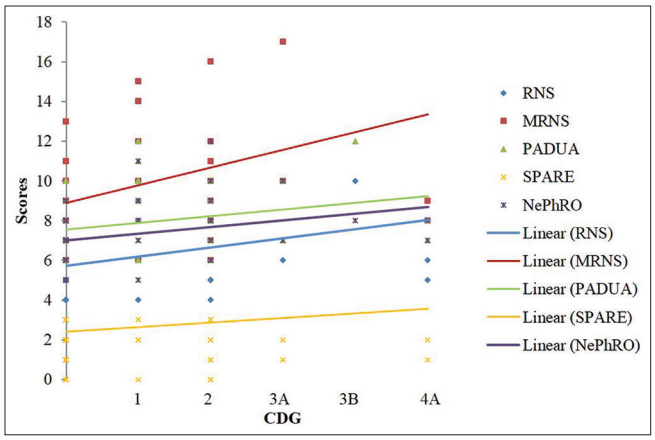

Figure 1: Scatter plot of score of each case against its CDG of complication. CDG = Clavien dindo grade of complication, MRNS = Modified renal nephrometry score, RNS = RENAL nephrometry score, PADUA = Preoperative aspects and dimensions used for an anatomical score, SPARE = Simplified PADUA RENAL nephrometry score

In our study, major complications (CDG 3+) were recorded in 7.8% of the cases (5/64). Kriegmair *et al.*[13] noted severe complications in 14.1% of the cases and a positive surgical margin in 4 cases (1.6%). Two patients (3.1%) required conversion to RN in our study, the average MRNS score of these 2 was 21 and the RNS was 10 - i.e. the 2 most complex lesions in our study as per the MRNS required conversion to RN due to hilar location and inability to achieve tumor free margins intraoperatively. Dahlkamp *et al.*[14] reported a conversion to RN in 3.7% of the RAPN cases and 14.8% of the OPN cases and hilar tumor infiltration (38.7%) and multifocality (22.6%) were the most frequent causes of conversion. Okhunov *et al.*[15] evaluated 101 patients and noted postoperative complications in 18 (18%) patients - eight CDG I, five Grade II, and six (6%) Grade III complications and two patients had positive margins (2%) on the final pathology. In our study also, two cases had positive surgical margins (3.4%).

In the study by Alma *et al.*[16], all the three scoring systems: RNS, PADUA, and C-index predicted the surgical complexity and surgical outcomes. Whereas Okhunov *et al.*,[15] compared PADUA, RENAL, and C-Index, and found that all the scores were associated with a decline in the eGFR, but did not have a significant correlation with the other measures of operative complexity, such as estimated blood loss, operative time, and perioperative complication rates. Furthermore, the PADUA and the RENAL scores were unable to discriminate between the moderate and high complexity tumors. Kriegmair *et al.*[13] compared the RENAL, PADUA, C-index, and the NePhRO score and found that all the scores correlated well with the ischemia time.

Veccia *et al.*[3] performed a meta-analysis of all the existing scores and found that all the scores were good predictors of complications, if evaluated as a continuous data. However,

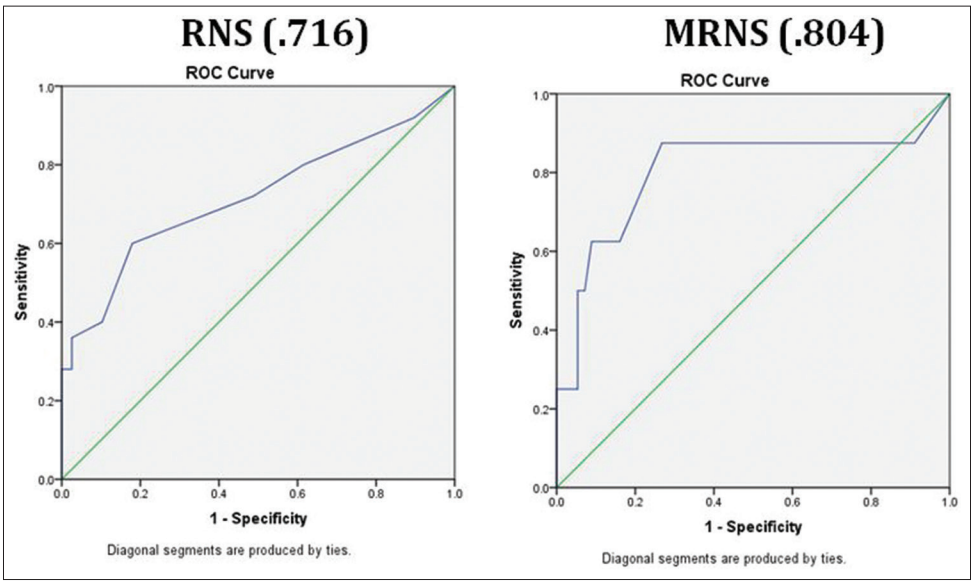

Figure 2: Area under ROC for prediction of complications. ROC = Receiver-operating characteristic, MRNS = Modified renal nephrometry score, RNS = Renal nephrometry score

when categorized into groups, the high complexity group in itself was not a definitive predictor of higher complication rate. None of the nephrometry scores included in their study was found to effectively predict the trifecta achievement. The categorical RENAL score (i.e. high complexity group) was the only score which was assessed for its ability to predict the presence of malignancy, but failed to do so. In our study, for the continuous scores, the MRNS scaled the severity of complications better than the RNS, PADUA, SPARE, NePhRO, and the C-index [Figure 1 Scatter plot score versus CDG]. As the categorical data, the high complexity group as per the MRNS was a better predictor of severe complications, conversion to RN, positive surgical margins and tumor histology. Based on these findings, we suggest that tumors with high complexity score on the MRNS (15–23) are not the ideal candidates for PN.

The trifecta outcomes and the MIC score are standardized systems for evaluating the outcomes of nephron-sparing surgery.[5,6] In our study, out of the 64 cases, the MIC was achieved in 85.9% of the cases and the trifecta in 71.9% of the cases. Borgmann *et al.*,[17] reported that the rate of achievement of MIC was significantly higher in the low complexity tumors than in the high complexity tumors. Among the RENAL, PADUA, C-Index, and DAP score, RENAL score correlated best with the achievement of MIC and the quantitative perioperative outcomes. Sharma *et al.*[18] compared RNS, PADUA, and C-index and found that only the C-index was able to predict the perioperative outcomes as well as the trifecta. The Meta-analysis by Veccia *et al.*,[3] comprehensively reviewed all the existing scores and found that only the PADUA score was a predictor of major complications. None of the other nephrometry scores, included in the analysis, could predict the achievement of trifecta. They also found that RPS had a higher predictive value for pelvicalyceal entry/repair and urine leak.

The MRNS score, described by Salah *et al.*,[4] has a range from 5 to 23. This helps in finer gradation while predicting the complications. In their study, they found it to be superior to the RNS for predicting the complications. Our study corroborates with their findings and further compares it to the other scores. We also found the MRNS to be an independent predictor of the trifecta outcome.

Strengths of our study are its prospective design, comprehensive comparison with the important nephrometry scores (RENAL, PADUA, C-index, SPARE, and NePhRO) and the standardized outcome assessment with the Trifecta and MIC. The limitations of this study are that the patients were operated upon by several surgeons and that we included only the OPN cases. We believe that the findings of OPN can be extended to the minimally invasive techniques as these nephrometry score are indicative of the tumor anatomy and complexity. Also the present study had a small sample size and the number of tumors of high complexity was low, and thus our findings need to be confirmed by larger studies.

CONCLUSIONS

The present study evaluated the MRNS and compared it to the existing scoring systems and found that MRNS, by enhancing the scores attributed to the key elements and by adding new elements, improves the predictive power of RNS. Due to a wider range of scale from 5–23, it also provides superior resolution while predicting the outcomes, including the trifecta achievement, in comparison to the other scores.

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