Salah *et al. Afr J Urol (2020) 26:45*
https://doi.org/10.1186/s12301-020-00056-3

African Journal of Urology

ORIGINAL RESEARCH

Open Access

Modified R.E.N.A.L nephrometry score for predicting the outcome following partial nephrectomy

Mohammed Salah, Mohammed S. ElSheemy*, Waleed Ghoneima, Mahmoud Abd El Hamid, Ayman Kassem, Ahmed Abdallah Ashmawy, Ismail R. Saad, Ashraf A. Mosharafa, Hosni Khairy Salem, Hesham Badawy and Ahmed Salem

Abstract

Background: It was difficult to compare the outcome of partial nephrectomy among different studies due to the absence of standardized description of different renal masses. This problem led to the development of nephrometry scoring systems. R.E.N.A.L. is among the commonest nephrometry scoring systems; however, some studies failed to find any relation between R.E.N.A.L. with perioperative outcome. We evaluated our designed newly modified nephrometry score in prediction of outcome following partial nephrectomy and compared its predictability versus original R.E.N.A.L.

Methods: Fifty-one patients with $cT_{1\text{-}2}N_0M_0$ renal masses amenable for partial nephrectomy were included prospectively. Different perioperative outcome variables were compared according to complexity level in R.E.N.A.L. and the newly modified nephrometry score.

Results: Clinical staging was T1a (21.6%), T1b (49%), T2a (25.5%), T2b (3.9%). Median R.E.N.A.L. was 9 (4–12). Hilar position and intrarenal pelvis were detected in 19.6% and 68.6%. Low, moderate and high complexity masses were found in 21.6%, 39.2% and 39.2%. Complications and rate of conversion to radical nephrectomy were 17 (33.3%) and 4 (7.8%). The only significantly affected variable ($p = 0.039$) by R.E.N.A.L. was rate of secondary intervention, but it was higher in low than in high complexity level. In the newly modified nephrometry score, complications ($p = 0.037$) and rate of positive surgical margin ($p = 0.049$) were significantly higher with increased complexity level. Although other variables (pelvi-calyceal system entry, operative time, blood loss, hemoglobin loss, blood transfusion and conversion to radical nephrectomy) did not show statistically significant difference according to both scores, they were better associated with the complexity level in the newly modified nephrometry score with their remarkable increase in the high when compared to the low complexity level.

Conclusions: The newly modified nephrometry score was associated with better prediction of outcome of partial nephrectomy when compared to R.E.N.A.L.

Keywords: Renal mass, Partial nephrectomy, Renal pelvis score, Nephrometry score, R.E.N.A.L

1 Background

The rate of detection of renal masses has been increased due to improved imaging techniques [1]. This raised the need for treatment modalities other than radical nephrectomy (RN) to preserve renal function as possible including partial nephrectomy (PN) [1–5]. It is indicated

*Correspondence: mohammedshemy@yahoo.com
Urology Department, Kasr Al-Ainy Hospitals, Faculty of Medicine, Cairo University, Cairo, Egypt

in localized renal masses (cT_1) [6]. Furthermore, PN can safely be performed in cT2 renal masses with acceptable technical and oncological outcomes and with maximal parenchymal preservation, especially in solitary kidney or bilateral tumors [2, 7, 8]. However, PN is associated with increased risk of overall complications [2, 4, 9].

Many studies were conducted to evaluate the outcome of PN, but it was difficult to compare them as there were no standardized criteria to unify the description of different renal masses. This problem led to the development of nephrometry scoring systems (NS) to unify as possible the description of the renal masses. There are many scoring systems including the PAUDA [10], the centrality index (C-index) method [11] and the R.E.N.A.L. NS [12]. Another problem in the management of renal masses using PN was the bias in decision which was based mainly on surgeon preferences and experience without standard criteria [12]. Consequently, these NS were tried to predict the outcome of PN [13]. This could help in decision making by proper selection of the surgical procedure.

R.E.N.A.L. is one of these nephrometry scoring systems that was thoroughly evaluated. However, some studies failed to find any relation between R.E.N.A.L. with operative parameters or postoperative outcome [13–18]. Thus, the need for continuous improvement in these NS is obvious for better prediction of the outcome and proper selection of the surgical technique.

Our aim was to evaluate our designed newly modified nephrometry score (MNS) in prediction of the outcome following PN for renal masses and to compare its predictability versus original R.E.N.A.L.

2 Methods

2.1 Study design and inclusion criteria

This was a prospective study for adult patients ($\geq$ 18 years old) who presented consecutively between September 2014 and December 2016 with $cT_{1\text{-}2}N_0M_0$ renal masses amenable for PN. Indications for PN were patients with solitary kidney, bilateral renal masses, chronic kidney disease or risk of future renal impairment as in cases of hypertension or diabetes, to preserve renal function. Additionally, patients with small renal masses <4 cm were included even with normal contralateral kidney. We excluded patients with previous renal or abdominal surgeries. The study was approved by institutional review board, and written informed consent was obtained from all patients.

2.2 Clinical assessment

Routine preoperative investigations were performed including CBC, coagulation profile and serum creatinine. Estimated glomerular filtration rate (eGFR) was calculated using the Modification of Diet in Renal Disease (MDRM) equation [19]. Contrast-enhanced cross-sectional imaging of chest, abdomen and pelvis (CT or MRI) for each patient was assessed by two uro-oncologists familiar with the Renal Pelvic Score (RPS) [20] and the R.E.N.A.L [12]. If the two members disagreed in the scoring, a third opinion was obtained.

2.3 Surgical management and postoperative care

After positioning of the patient in the lateral decubitus position, all patients underwent open PN with a flank incision performed with excision of the 11th rib to gain access to the targeted kidney. Trans-gerotal approach was adopted in all cases, where dissection of the perirenal fat was done except the area surrounding the mass. Site of the mass was identified intraoperatively by either direct visualization of the mass or ultrasound guidance, especially if the mass was totally endophytic. After intraoperative mass assessment, we decided to proceed with either warm ischemia or no ischemia. The incision line for the mass, outside its capsule and surrounding a rim of normal parenchyma, was outlined then deepened using a combination of blunt and sharp dissection, then the mass was removed with its surrounding fat. A sample from the deepest point of the bed was obtained for histopathological examination. Bleeding vessels and injuries to pelvi-calyceal system were repaired. Reconstruction of the renal bed was done by placement of hemostatic materials in the form of an oxidized cellulose polymer and/or oxidized regenerated cellulose. Parenchymal closure with the covering capsule was done using interrupted absorbable 2/0 sutures with the aid of oxidized cellulose polymer to support the sutures. We didn't routinely insert a ureteric stent. Urethral catheter was removed on (day 1) while the drain was left for an average of 3 days then removed with discharge of the patient.

Follow-up visits were at 1, 4 and 12 week then at 6 and 12 months postoperatively. In each visit, evaluation was done by serum creatinine, eGFR, urine analysis and US. Additionally, CT or MRI was performed at 6 and 12 months.

2.4 Data collection

Different outcome parameters were reported including warm ischemia time (WIT), operative time, estimated blood loss, blood transfusion, renal vascular injury, ureteric or renal pelvis injury, pelvi-calyceal system (PCS) entry, conversion to RN, urinary leakage, length of hospital stay, postoperative renal function and pathology findings.

2.5 Newly modified nephrometry score (MNS)

We compared different outcome parameters according to R.E.N.A.L. and RPS. We modified R.E.N.A.L. with incorporation of new items in the score including hilar position of the mass as a numerical score not only a descriptive character (scored 0 or 5) and RPS (scored 1 or 3 according to the percentage of renal pelvis area contained inside the volume of the renal parenchyma whether less or more than 50%; respectively). Furthermore, we changed the score points given to some items of the original R.E.N.A.L. according to our point of view regarding their importance in describing the complexity of the mass. We kept the score of the radius "R" and relation to polar lines "L" as 1, 2 or 3, but we changed the score of the nearness to PCS and sinus "N" to 1, 2 or 4 and the score of the endophytic nature of the mass "E" to 1, 2 or 5. Accordingly, the new score is ranging from 5 to 23. It is classified into mild complexity (5–9), moderate complexity (10–14) or high complexity (15–23). A renal mass can be described using the MNS as (R + E + N + apx + L + H + RPS). The newly modified nephrometry score was used to compare the different outcome parameters to evaluate its predictability and whether it was better or not than R.E.N.A.L.

2.6 Statistical analysis

The Statistical Package of Social Science (SPSS) Software program, version 20, was used for statistical analysis. Nominal values were compared using Chi-square (χ^2) test or Fisher-exact test as appropriate. For comparing numerical values of the three complexity groups, the one way ANOVA (with Post Hoc analysis) or Kruskal–Wallis test were used. p values < 0.05 were considered statistically significant.

3 Results

3.1 Demographic and perioperative data

Fifty-one consecutive patients with renal masses were included. The baseline characteristics are shown in Table 1. Perioperative data are presented in Table 2. Perioperative complications were detected in 17 (33.3%) patients. Injury to the renal artery was reported in 2 patients. Exploration of the renal artery revealed an intimal crack in the first patient; which was repaired, and a blood clot in the second patient; which was dislodged by Fogarty catheter. Postoperative hematuria that failed to respond to intravenous fluid and anti-bleeding measures were detected in 2 patients on day 5 and day 7, respectively. Diagnostic angiography was done and showed AV fistula formation which was controlled by injection of histoacryl. There were 6 cases of postoperative urine leakage. This was associated with perinephric collection in 2 patients. Four cases required double-J stent insertion, while the other 2 cases were successfully managed conservatively by urethral catheter insertion or extending the duration of the already inserted catheter. No pre- or intraoperative stenting was done except for 1 patient who had ureteric injury during dissection of a lower polar mass. Conversion to RN was mandated in 4 (7.8%) patients due to inadequate residual renal tissue after PN (1), severe injury to PCS after excision of the mass with impossible repair (1), failure to localize the site of a completely endophytic renal mass close to renal hilum even after the use of ultrasound (1) and involvement of the hilar vessels by the renal mass in the 4th patient.

Six patients developed postoperative renal function deterioration. Only one of these six patients had normal preoperative renal functions. The preoperative eGFR was (91 ml/min). The creatinine raised from 1 to 3.5 mg/dl immediately postoperatively. On follow-up after 3 months, eGFR improved to 88 ml/min; which was very close to preoperative reading. No patient developed *recurrence after a 1 year follow-up.*

3.2 Pathological data

The clear cell type was the most dominant pathological finding (26 cases) (Table 2). The cases of positive surgical margins (5.9%) were followed up every 3 months with cross-sectional imaging.

3.3 Effect of complexity on outcome according to R.E.N.A.L. and MNS

Different perioperative factors were compared according to complexity level in R.E.N.A.L. (Table 3) and MNS (Table 4). There was no statistically significant difference between the complexity groups in the preoperative characteristics in both scores. In R.E.N.A.L., the only detected variable that was affected significantly ($p = 0.039$) by the complexity level was the need for secondary intervention. The hilar position (H) and RPS showed statistically significant difference only according to MNS as they were not included in the original R.E.N.A.L. In MNS, the complication rate was significantly higher with increase in the complexity level ($p = 0.037$). Furthermore, the rate of complications was nearly doubled while moving from a low complexity level to a higher level (13.3% vs 30% vs 56.3%) which was completely different from the original R.E.N.A.L. The rate of positive surgical margin showed statistically significant difference according to MNS ($p = 0.049$) and was found only in the highest complexity level while it showed no significant difference according to the original R.E.N.A.L in which it was found in both moderate and high complexity levels. Although secondary intervention showed statistically significant difference in the original score ($p = 0.039$), it was higher in the low

Table 1 Preoperative demographic data of the patients and characteristics of the renal masses

	51 patients
Age (years)	50.19 ± 13.25 (20–80)
Sex: male/female	29 (56.9%)/22 (43.1%)
Medical disease (DM, HTN, IHD and/or stroke)	25 (49%)
CKD (ml/min/1.73 m^2): > 90/60–89/30–59	17 (33.3%)/26 (51%)/8 (15.7%)
Solitary kidney	2 (3.9%)
Side: right/left	30 (58.8%)/21 (41.2%)
Clinical T	
1a	11 (21.6%)
1b	25 (49%)
2a	13 (25.5%)
2b	2 (3.9%)
Position: anterior/posterior/"X"	15 (29.4%)/28 (54.9%)/8 (15.7%)
Hilar position	10 (19.6%)
Renal Pelvic Score: extrarenal/intrarenal	16 (31.4%)/35 (68.6%)
Complexity: low/moderate/high	11 (21.6%)/20 (39.2%)/20 (39.2%)
Modified complexity: low/moderate/high	15 (29.4%)/20 (39.2%)/16 (31.4%)
Indications for PN	
CKD	3 (5.9%)
Medical disease (HTN + DM)	14 (27.4%)
CKD + medical disease	4 (7.8%)
SRM/peripheral mass	24 (47.0%)
AML with bleeding	3 (5.9%)
Solitary	1 (2%)
Bilateral masses	2 (3.9)
BMI (kg/m^2)	29.8 ± 5.2 (21–42)
ASA Score	1 (1–2)
Pre-Op eGFR (ml/min/1.73 m^2)	84.6 ± 24.5 (40–141)
Pre-Op Hb (gm/dl)	13.2 ± 1.7 (9.1–16.4)
R.E.N.A.L.	9 (4–12)
MNS	12 (6–22)

Values were presented as mean ± SD (range), median (range) or number of patients (%) as appropriate

ASA American society of anesthesiology, *BMI* body mass index, *CKD* chronic kidney disease, *DM* diabetes mellitus, *eGFR* estimated glomerular filtration rate, *Hb* hemoglobin, *HTN* hypertension, *IHD* ischemic heart disease, *MNS* newly modified nephrometry score, *Pre-Op* preoperative, *SRM* small renal mass

complexity level (18.2%) than in the high complexity level (5%). The relation of the rate of secondary intervention became better associated with the complexity level in the MNS although the significant difference was abolished ($p = 0.757$). Although the rate of PCS entry did not show statistically significant difference according to complexity level in both scores, it was more associated with the complexity level in MNS with nearly doubling when comparing the low and high levels (33.3% vs 62.5%, respectively) while in R.E.N.A.L, the rate of PCS entry was higher in the low than the moderate complexity. This more association with the level of complexity, in the absence of significant difference, was also observed in MNS when compared with the original score in many other perioperative outcome variables including operative time, WIT, blood loss, hemoglobin loss, blood transfusion, ureteric injury and conversion to RN.

3.4 Predicting factors for postoperative complications

This was confirmed by analysis of predicting factors for postoperative complications (Table 5). The detected significant predicting factors were the complexity level according to MNS ($p = 0.037$), MNS ($p = 0.014$) and hilar position ($p = 0.001$).

4 Discussion

R.E.N.A.L. is one of the nephrometry scoring systems that proved its reproducibility and minimal interobserver variability [21, 22]. It was used to predict the outcome of PN based on the complexity of renal mass

Table 2 Perioperative data, complications and follow-up

Operative time (h)	3 ± 0.7 (1.75–5)
Ischemia type: warm ischemia/zero ischemia	40 (78.4%)/11 (21.6%)
WIT (min)	15.1 ± 9.8 (0–40)
PCS entry	26 (51%)
Blood transfusion	9 (17.6%)
Blood loss (ml)	250 (50–1500)
Conversion to radical nephrectomy	4 (7.8%)
Post-Op Hb (gm/dl)	11.8 ± 1.8 (7.1–15.8)
Hb loss (gm/dl)	1 (0.10–5.3)
Perioperative complications[a]	17 (33.3%)
Grade I	
Fever	7 (13.7%)
Grade II	
Blood transfusion	9 (17.6%)
Leakage (conservative)	1 (2%)
Perinephric collection and leak (conservative)	1 (2%)
Grade III	
Leak (endoscopic stenting)	3 (5.88%)
Perinephric collection and leak (endoscopic stenting)	1 (2%)
AVF (Embolization)	2 (3.9%)
Ureteric injury	2 (3.9%)
Renal artery thrombosis/intimal injury	2 (3.9%)
Drain removal/length of hospital stay (days)	5 (3–28)/5 (3–29)
Pathological T	
Benign	11 (21.6%)
1a/1b	9 (17.6%)/17 (33.3%)
2a/2b	8 (15.7%)/5 (5.9%)
3a	1 (2%)
Histologic type	
Clear cell	26 (51%)
Papillary/chromophobe/esinophilic	6 (11.8%)/7 (13.7%)/1 (2%)
Benign lesions: (AML/oncocytoma)	11 (21.56%)
Fuhrman grade: I/II/III	18 (35%)/21 (41.2%)/1 (2%)
Positive surgical margin	3 (5.9%)
Post-Op eGFR 3 mo (ml/min/1.73 m^2)	77.7 ± 22.1 (21.8–130)

Values are presented as mean ± SD (range), median (range) or number of patients (%) as appropriate

AML angiomyolipoma, *AVF* arteriovenous fistula, *eGFR* estimated glomerular filtration rate, *Hb* hemoglobin, *PCS* pelvi-calyceal system, *Post-Op* postoperative, *WIT* warm ischemia time

[a] According to Clavien-Dindo classification system

in multiple studies; most of them were retrospective. In our prospective study, we aimed at evaluating the ability of R.E.N.A.L., and our MNS in prediction of the risk of perioperative complications, conversion to RN and other outcome variables. We had 17 (33%) patients with perioperative complications. This was in the range of reported complications in other studies (24.24–38.46%) [2, 13, 23–26]. We had 4 cases (7.8%) of conversion to RN which was similar to that found in different studies (6–16.3%) [17, 27, 28].

Similar to our study, many studies showed no significant difference in the rate of complications [13–17, 27], estimated amount of blood loss [15–18, 27] transfusion rate [13, 14, 18, 27], ischemia time [13–16], length of hospital stay [13, 15, 16, 18, 27], operative time [13–16, 18, 23, 27], positive surgical margins, [27] and change in eGFR [14, 16, 18, 27], in relation to R.E.N.A.L. and different complexity grades. On the other hand, other studies reported significant difference in the rate of some outcome parameters according to R.E.N.A.L. including

Table 3 Renal mass complexity according to R.E.N.A.L. NS in relation to outcome parameters

	Complexity level according to R.E.N.A.L.			*p*
	Low (4–6) 11 patients	**Moderate (7–9) 20 patients**	**High (10–12) 20 patients**	
Age (years)	48.1 ± 13.1 (20–59)	50.3 ± 10.1 (34–65)	51.1 ± 16.2 (20–80)	.861
BMI (kg/m^2)	32 ± 6.7 (22–42)	28.5 ± 4.3 (22–36)	29.6 ± 4.9 (21–39)	.117
ASA Score	1 (1–2)	1 (1–2)	2 (1–2)	.441
Pre-Op eGFR (ml/min/1.73m^2)	86.1 ± 20.9 (55–141)	76.9 ± 18.6 (43–126)	91 ± 30 (40–140)	.183
Pre-Op Hb (gm/dl)	14.1 ± 1.05 (13–15.9)	13.2 ± 1.8 (10.5–16.4)	12.6 ± 1.7 (9.1–15.5)	.064
Sex: male/female	7 (63.6%)/4 (36.4%)	13 (65%)/7 (35%)	9/(45%)/11 (55%)	.388
Side: right/left	8 (72.7%)/3 (27.3%)	12 (60%)/8 (40%)	10 (50%)/10 (50%)	.465
CKD (ml/min/1.73m^2)				.104
> 90	4/11 (36.4%)	3/20 (15%)	10/20 (50%)	
60–89	6/11 (54.5%)	14/20 (70%)	6/20 (30%)	
30–59	1/11 (9.1%)	3/20 (15%)	4/20 (20%)	
Clinical T				.095
T_1	10/11 (90.9%)	15/20 (75%)	11/20 (55%)	
T_2	1/11 (9.1%)	5/20 (25%)	9/20 (45%)	
OR time (h)	2.6 ± 0.57 (1.7–3.5)	3.1 ± 0.78 (2–5)	3.03 ± 0.65 (2–4.5)	.174
WIT (min)	14 (0–20)	15 (0–30)	19 (0–40)	.343
LOS (days)	4 (3–9)	5 (4–29)	5 (4–11)	.109
Hb loss (gm/dl)	1 (0.4–3.5)	1 (0.2–3.7)	1 (0.1–5.3)	.788
Blood loss (ml)	150 (50–1500)	300 (100–900)	300 (50–1100)	.272
Ischemia type				.251
Warm ischemia	7/11 (63.6%)	18/20 (90%)	15/20 (75%)	
No ischemia	4/11 (36.4%)	2/20 (10%)	5/20 (25%)	
Hilar position	0/11	3/20 (5.9%)	7/20 (13.7%)	.053
RPS				
Intrarenal/extrarenal	7 (63.6%)/4 (36.4%)	14 (70%)/6 (30%)	14 (70%)/6 (30%)	.922
PCS entry	5/11 (45.5%)	8/20 (40%)	13/20 (65%)	.263
Post-Op Hb (gm/dl)	12.6 ± 1.5 (10 - 14.3)	11.9 ± 1.6 (9 - 15.8)	11.3 ± 2 (7.1–15)	.148
Total complications	2/11 (18.2%)	9/20 (52.9%)	6/20 (30%)	.292
Secondary intervention	2/11 (18.2%)	7/20 (35%)	1/20 (5%)	.039*
VC	1/11 (9.1%)	2/20 (10%)	1/20 (5%)	1
Ureteric injury	0/11	2/20 (10%)	0/20	.341
Blood transfusion	2/11 (18.2%)	3/20 (15%)	4/20 (20%)	1
Leakage	0/11	5/20 (25%)	1/20 (5%)	.124
Drain removal (d)	4 (3–8)	4.5 (3–28)	5 (4–7)	.243
Conversion to RN	1/11 (9.1%)	1/20 (5%)	2/20 (10%)	1
RF impairment	1/11 (9.1%)	2/20 (10%)	3/20 (11.8%)	1
Positive margin	0/11	1/20 (5%)	2/20 (10%)	.789
Post-Op eGFR 3mo (ml/min/1.73m^2)	78.6 ± 17.5 (60–114.3)	74.8 ± 19.3 (32–117)	80.1 ± 27 (21.8–130)	.750

Values are presented as mean ± SD (range), Median (range) or number of patients (%) as appropriate

AML angiomyolipoma, *ASA* American society of anesthesiology, *BMI* body mass index, *CKD* chronic kidney disease, *eGFR* estimated glomerular filtration rate, *Hb* hemoglobin, *LOS* length of hospital stay, *OR* operative, *PCS* pelvi-calyceal system, *Post-Op* postoperative, *Pre-Op* preoperative, *RF* renal function, *RN* radical nephrectomy, *RPS* renal pelvic score, *VC* vascular complications, *WIT* warm ischemia time

*Significant

the rate of total complications [18, 23], ischemia time [14, 15, 17, 18, 23, 27], the total operative time [17], estimated blood loss [14–23], length of hospital stay [14–23], renal function impairment [15] and the possibility of conversion to RN [17, 27].

As there was no statistically significant difference in nearly all of the outcome parameters according to

Table 4 Renal mass complexity according to newly modified score in relation to outcome parameters

	Complexity according to MNS			*p*
	Low (5–9) 15 patient	Moderate (10–14) 20 patient	High (15–23) 16 patient	
Age (years)	49.3 ± 12.3 (20–63)	51.9 ± 13.7 (30–80)	48.8 ± 13.9 (20–65)	.941
BMI (kg/m^2)	31.4 ± 6.2 (22–42)	27.3 ± 4.1 (21–36)	31.4 ± 4.5 (25–39)	.022*
ASA Score	1 (1–2)	1 (1–2)	2 (1–2)	.404
Pre-Op eGFR (ml/min/1.73m^2)	84.9 ± 18.7 (55–141)	81.7 ± 25.3 (43–130)	87.3 ± 29.1 (40–140)	.788
Pre-Op Hb (gm/dl)	14 ± 1.3 (11.4–16.4)	12.7 ± 1.9 (9.1–15.8)	13 ± 1.5 (10.1–15.6)	.091
Sex: male/female	8 (53.3%)/7 (46.7%)	11 (55%)/9 (45%)	10 (56.9%)/6 (37.5%)	.856
Side: right/left	11 (73.3%)/4 (26.7%)	8 (40%)/12 (60%)	11 (68.8%)/5 (31.3%)	.087
CKD (ml/min/1.73m^2)				.583
> 90	5/15 (33.3%)	5/20 (25%)	7/16 (43.8%)	
60–89	9/15 (60%)	11/20 (55%)	6/16 (37.5%)	
30–59	1/15 (6.7%)	4/20 (20%)	3/16 (18.8%)	
Clinical T				.216
T_1	13/15 (86.7%)	14/20 (70%)	9/16 (56.2%)	
T_2	2/15 (13.3%)	6/20 (30%)	7/16 (43.8%)	
OR time (h)	2.7 ± 0.67 (1.7–4.25)	3 ± 0.79 (2–5)	3.1 ± 0.57 (2.25–4)	.153
WIT (min)	14 (0–20)	18.5 (0–40)	16.5 (0–27)	.070
LOS (day)	4 (3–9)	5 (4–29)	5 (4–14)	.077
Hb loss (gm/dl)	1 (0.2–3.5)	1 (0.10–3.7)	1 (0.1–5.3)	.937
Blood loss (ml)	150 (50–1500)	275 (50–900)	475 (50–1100)	.081
Ischemia type				.317
Warm ischemia	11/15 (73.3%)	18/20 (90%)	11/16 (68.8%)	
No ischemia	4/15 (26.7%)	2/20 (10%)	5/16 (31.2%)	
Hilar position	0/10	0/10	10/10 (100%)	<.001*
RPS				.049*
Intrarenal/extrarenal	7 (46.7%)/8 (53.3%)	14 (70%)/6 (30%)	14 (87.5%)/2 (12.5%)	
PCS entry	5/15 (33.3%)	11/20 (55%)	10/16 (62.5%)	.241
Post-Op Hb (gm/dl)	12.7 ± 1.5 (10–15.8)	11.4 ± 1.8 (7.1–14.5)	11.5 ± 1.7 (8.6–15)	.074
Total complications	2/15 (13.3%)	6/20 (30%)	9/16 (56.3%)	.037*
Secondary intervention	2/15 (13.3%)	5/20 (25%)	3/16 (18.8%)	.757
VC	1/15 (6.7%)	2/20 (10%)	1/16 (6.3%)	1
Ureteric injury	0/15	1/20 (5%)	1/16 (6.3%)	1
Blood Transfusion	2/15 (13.3%)	2/20 (10%)	5/16 (31.3%)	.269
Leakage	0/15	4/20 (20%)	2/16 (12.5%)	.255
Drain removal (d)	4 (3–8)	4.5 (4–28)	5 (3–14)	.200
Conversion to RN	1/15 (6.7%)	1/20 (5%)	2/16 (12.5%)	.818
RF impairment	1/15 (6.7%)	2/20 (10%)	3/16 (18.8%)	.647
Positive margin	0/15	0/20	3/16 (18.8%)	.049*
Post-Op eGFR 3mo (ml/min/1.73m^2)	79.6 ± 15.4 (60–114)	78.3 ± 23.1 (27–117)	75.3 ± 26.7 (21.8–130)	.856

Values are presented as mean ± SD (range), Median (range) or number of patients (%) as appropriate

AML angiomyolipoma, *ASA* American society of anesthesiology, *BMI* body mass index, *CKD* chronic kidney disease, *eGFR* estimated glomerular filtration rate, *Hb* hemoglobin, *LOS* length of hospital stay, *MNS* newly modified nephrometry score, *OR* operative, *PCS* pelvi-calyceal system, *Post-Op* postoperative, *Pre-Op* preoperative, *RF* renal function, *RN* radical nephrectomy, *RPS* renal pelvic score, *VC* vascular complications, *WIT* warm ischemia time

*Significant

different complexity levels using R.E.N.A.L., we tried to modify R.E.N.A.L. hoping that it will better predict the postoperative outcome and complications. We incorporated both the hilar position and RPS. Additionally, a significant limitation to the original R.E.N.A.L was giving an equal strength to its different components

Table 5 Predicting factors for postoperative complications

	Patient without complications 34 patient	Patient with complications 17 patient	*p*
Age (years)	50.4 ± 14.76 (20–80)	49.6 ± 9.9 (30–65)	.815
BMI (kg/m^2)	29.1 ± 5 (21–40)	31.3 ± 5.6 (25–42)	.151
ASA Score	1 (1–2)	2 (1–2)	.327
Pre-Op eGFR (ml/min/1.73m^2)	86.6 ± 26.2 (43–141)	80 ± 20.9 (40–130)	.372
Pre-Op Hb (gm/dl)	13.3 ± 1.8 (9.1–16.4)	12.9 ± 1.5 (10.8–15.8)	.399
Sex			.842
Male	19/29 (65.5%)	10/29 (34.5%)	
Female	15/22 (68.2%)	7/22 (31.8%)	
Side			.07
Right	23/30 (76.7%)	7/30 (23.3%)	
Left	11/21 (52.4%)	10/21 (47.6%)	
Solitary kidney	1/2 (50%)	1/2 (50%)	1
CKD (ml/min/1.73m^2)			.381
> 90	13/17 (76.5%)	4/17 (23.5%)	
60–89	15/26 (57.7%)	11/26 (42.3%)	
30–59	6/8 (75%)	2/8 (25%)	
cT			.192
T1	26/36 (72.2%)	10/36 (27.8%)	
T2	8/15 (53.3%)	7/15 (46.7%)	
RPS			.393
Intrarenal	22/35 (62.9%)	13/35 (37.1%)	
Extrarenal	12/16 (75%)	4/16 (25%)	
R			.122
1	10/11 (90.9%)	1/11 (9.1%)	
2	17/27 (63%)	10/27 (37%)	
3	7/13 (53.8%)	6/13 (46.2%)	
E			.421
1	10/15 (66.7%)	5/15 (33.3%)	
2	19/26 (73.1%)	7/26 (26.9%)	
3	5/10 (50%)	5/10 (50%)	
N			.755
1	10/15 (66.7%)	5/15 (33.3%)	
2	9/12 (75%)	3/12 (25%)	
3	15/24 (62.5%)	9/24 (37.5%)	
L			.387
1	7/8 (87.5%)	1/8 (12.5%)	
2	11/17 (64.7%)	6/17 (35.3%)	
3	16/26 (61.5%)	10/26 (38.5%)	
Hilar position	2/10 (20%)	8/10 (80%)	.001*
Complexity			.292
Low	9/11 (81.8%)	2/11 (18.2%)	
Moderate	11/20 (55%)	9/20 (45%)	
High	14/20 (70%)	6/20 (30%)	
Modified complexity			.037*
Low	13/15 (86.7%)	2/15 (13.3%)	
Moderate	14/20 (70%)	6/20 (30%)	
High	7/16 (43.8%)	9/16 (56.2%)	
R.E.N.A.L.	8 (4–12)	9 (6–11)	.151
MNS	11 (6–19)	15 (7–22)	.014*

Table 5 (continued)

Values are presented as mean ± SD (range), median (range) or number of patients (%) as appropriate

ASA American society of anesthesiology, *BMI* body mass index, *CKD* chronic kidney disease, *eGFR* estimated glomerular filtration rate, *Hb* hemoglobin, *MNS* newly modified nephrometry score, *Pre-Op* preoperative, *RPS* renal pelvic score

*Significant

although some items may affect the complexity of the surgery more than others. Consequently, we modified the scoring of some items with giving more strength to E and N. These modifications were supported by what reported in the previous literature. Tomaszewski and colleagues evaluated the renal pelvic anatomy as an independent predictor of urine leak in 255 patients undergoing open PN. Despite the presence of more lesions with higher R.E.N.A.L. scores in patients with an extrarenal pelvis, the presence of an intrarenal pelvis was highly independently associated with risk of urine leak and rate of secondary intervention [20]. This was confirmed in other studies [29]. In the study reported by Liu et al. [18], only nearness to the collecting system "N", out of the five components of R.E.N.A.L., was significantly associated with both incidence of complications and postoperative hemorrhage. Furthermore, Bruner et al. [30] reported that "E" score out of other components of R.E.N.A.L. was a significant predictor of postoperative urine leak. Tomaszewski et al. [29] reported that "E" score had a strong independent association with urine leak while the overall NS and its other components were not associated with urine leak.

The application of these modifications was associated with marked improvement in the ability of the complexity level to predict different outcome parameters. This was confirmed by analysis of different predicting factors for occurrence of complications which revealed MNS, complexity level according to MNS and hilar position as the only significant predictors. However, original R.E.N.A.L or its individual components (R, E, N, L) were found to be non-significant.

Our study has some limitations. The most important one is the relatively small sample size. Another limiting factor was the use of warm ischemia in some patients and zero ischemia in others. Moreover, we did not evaluate the split renal function. Furthermore, we had different pathologies including benign lesions. However, our newly modified score was associated with better prediction of the outcome of PN including complications even in the presence of a small sample size. The comparison of MNS versus R.E.N.A.L. added to the strength of the study. The prospective evaluation is another strong point. The short period of recruitment of patients with use of the same surgical technique by the same surgeon helped to abolish their effects on outcome. These finding will be better confirmed in a larger studies using the same ischemia protocol. Additionally, a longer follow-up may help to detect the effect of positive surgical margin on the rate of recurrence free survival.

5 Conclusions

The newly modified nephrometry score was associated with better prediction of the outcome of PN when compared to R.E.N.A.L. nephrometry score. Thus, it can be used for better prediction of the outcome following partial nephrectomy.

Abbreviations

eGFR: Estimated glomerular filtration rate; MDRM: Modification of diet in renal disease equation; MNS: Newly modified nephrometry score; NS: Nephrometry scoring systems; PCS: Pelvi-calyceal system entry; PN: Partial nephrectomy; RPS: Renal Pelvic Score; RN: Radical nephrectomy; WIT: Warm ischemia time.

Acknowledgements

Not applicable.

Authors' contributions

MS: protocol development and research design, data collection and management, manuscript writing/editing. MSE: protocol development and research design, data collection and management, data analysis, manuscript writing/editing, supervision. AS: protocol development, data collection, supervision. MA: protocol development, data collection. AK: protocol development, data collection. AAA: protocol development, data collection. IRS: protocol development, data collection. AAM: protocol development, data collection. HKS: protocol development, data collection. HB: protocol development and research design, supervision. WG: protocol development, data collection. All authors read and approved the final manuscript.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

All procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Cairo University - Faculty of Medicine - Research Ethics Committee on 12/03/2014. [Committee's reference number 12032014]. A written Informed consent was obtained from all patients included in the study.

Consent for publication

Not applicable.

Competing interests

Prof Ashraf Mosharafa, Editor-in-Chief of the journal confirms that he was not involved in the editorial processing or peer review process for this manuscript. The authors declare that they have no conflict of interest.

Received: 13 January 2020 Accepted: 20 July 2020
Published online: 03 October 2020

References

1. Hollingsworth JM, Miller DC, Daignault S et al (2006) Rising incidence of small renal masses: a need to reassess treatment effect. J Natl Cancer Inst 98(18):1331–1334
2. Mir MC, Derweesh I, Porpiglia F et al (2017) Partial nephrectomy versus radical nephrectomy for clinical T1b and T2 renal tumors: a systematic review and meta-analysis of comparative studies. Eur Urol 71(4):606–617 **(Review)**
3. McKiernan J, Simmons R, Katz J et al (2002) Natural history of chronic renal insufficiency after partial and radical nephrectomy. Urology 59(6):816–820
4. Uzzo RG, Novick AC (2001) Nephron sparing surgery for renal tumors: indications, techniques and outcomes. J Urol 166(1):6–18
5. Kunkle DA, Egleston BL, Uzzo RG (2008) Excise, ablate or observe: the small renal mass dilemma–a meta-analysis and review. J Urol 179(4):1227–1234
6. Ljungberg B, Albiges L, Bensalah K et al (2017) EAU guidelines on renal cell carcinoma: 2017 update. https://uroweb.org/guideline/renal-cell-carcinoma/. Accessed 15 Dec 2017
7. Long CJ, Canter DJ, Kutikov A et al (2012) Partial nephrectomy for renal masses ≥ 7 cm: technical, oncological and functional outcomes. BJU Int 109(10):1450–1456
8. Lee HJ, Liss MA, Derweesh IH (2014) Outcomes of partial nephrectomy for clinical T1b and T2 renal tumors. Curr Opin Urol 24(5):448–452
9. Van Poppel H, Da Pozzo L, Albrecht W et al (2007) A prospective randomized EORTC intergroup phase 3 study comparing the complications of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol 51(6):1606–1615
10. Ficarra V, Novara G, Secco S et al (2009) Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for Nephron-Sparing Surgery. Eur Urol 56(5):786–793
11. Simmons MN, Ching CB, Samplaski MK et al (2010) Kidney tumor location measurement using the C index method. J Urol 183(5):1708–1713
12. Kutikov A, Uzzo RG (2009) The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol 182(3):844–853
13. Roushiasa S, Vasdeva N, Ganai B et al (2013) Can the R.E.N.A.L nephrometry score preoperatively predict postoperative clinical outcomes in patients undergoing open and laparoscopic partial nephrectomy? Curr Urol 7(2):90–97
14. Hayn MH, Schwaab T, Underwood W et al (2011) RENAL nephrometry score predicts surgical outcomes of laparoscopic partial nephrectomy. BJU Int 108(6):876–881
15. Okhunov Z, Rais-Bahrami S, George AK et al (2011) The comparison of three renal tumor scoring systems: C-Index, P.A.D.U.A., and R.E.N.A.L. nephrometry scores. J Endourol 25(12):1921–1924
16. Mufarrij PW, Krane LS, Rajamahanty S et al (2011) Does nephrometry scoring of renal tumors predict outcomes in patients selected for robot-assisted partial nephrectomy? J Endourol 25(10):1649–1653
17. Matos AC, Dall'Oglio MF, Colombo JR Jr et al (2017) Predicting outcomes in partial nephrectomy: Is the renal score useful? Int Braz J Urol 43(3):422–431
18. Liu ZW, Olweny EO, Yin G et al (2013) Prediction of perioperative outcomes following minimally invasive partial nephrectomy: role of the R.E.N.A.L nephrometry score. World J Urol 31(5):1183–1189
19. Levey AS, Greene T, Kusek J et al (2000) A simplified equation to predict glomerular filtration rate from serum creatinine [abstract A0828]. J Am Soc Nephrol 11:155A
20. Tomaszewski JJ, Cung B, Smaldone MC et al (2014) Renal pelvic anatomy is associated with incidence, grade, and need for intervention for urine leak following partial nephrectomy. Eur Urol 66(5):949–955
21. Montag S, Waingankar N, Sadek MA et al (2011) Reproducibility and fidelity of the R.E.N.A.L. nephrometry score. J Endourol 25(12):1925–1928
22. Weight CJ, Atwell TD, Fazzio RT et al (2011) A multidisciplinary evaluation of inter-reviewer agreement of the nephrometry score and the prediction of long-term outcomes. J Urol 186(4):1223–1228
23. Simhan J, Smaldone MC, Tsai KJ et al (2011) Objective measures of renal mass anatomic complexity predict rates of major complications following partial nephrectomy. Eur Urol 60(4):724–730
24. Deklaj T, Lifshitz DA, Shikanov SA et al (2010) Laparoscopic radical versus laparoscopic partial nephrectomy for clinical T1bN0M0 renal tumors: comparison of perioperative, pathological, and functional outcomes. J Endourol 24(10):1603–1607
25. Roos FC, Brenner W, Thomas C et al (2012) Functional analysis of elective nephron-sparing surgery vs radical nephrectomy for renal tumors larger than 4 cm. Urology 79(3):607–613
26. Brewer K, O'Malley RL, Hayn M et al (2012) Perioperative and renal function outcomes of minimally invasive partial nephrectomy for T1b and T2a kidney tumors. J Endourol 26(3):244–248
27. Long JA, Arnoux V, Fiard G et al (2013) External validation of the RENAL nephrometry score in renal tumours treated by partial nephrectomy. BJU Int 111(2):233–239
28. Galvin DJ, Savage CJ, Adamy A et al (2011) Intraoperative conversion from partial to radical nephrectomy at a single institution from 2003 to 2008. J Urol 185(4):1204–1209
29. Tomaszewski JJ, Smaldone MC, Cung B et al (2014) Internal validation of the renal pelvic score: a novel marker of renal pelvic anatomy that predicts urine leak after partial nephrectomy. Urology 84(2):351–357
30. Bruner B, Breau RH, Lohse CM et al (2011) Renal nephrometry score is associated with urine leak after partial nephrectomy. BJU Int 108(1):67–72

Publisher's Note