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Predicting Bleeding Related Events in Robotic-Assisted Partial Nephrectomy for Angiomyolipoma: Simplifying Risk Assessment with Tumor Diameter and Depth, A Retrospective Study

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Background: Evaluating risk factors for bleeding events in robot-assisted partial nephrectomy (RAPN) for renal angiomyolipoma (RAML) is essential for improving surgical outcomes.

Methods: We performed a retrospective analysis of patients who underwent RAPN for renal masses between May 2019 and June 2023 at a single medical center, categorizing them into AML and non-AML groups. We assessed demographic data, perioperative complications, and postoperative outcomes. Preoperative imaging was reviewed to calculate R.E.N.A.L and PADUA nephrometry scores. Receiver operating characteristic (ROC) curve analysis was used to evaluate the accuracy of risk factors related to estimated blood loss (EBL) and blood transfusion.

Results: Among 255 patients, 71 (27.8%) had AML, and 184 (72.2%) had non-AML. The average age was 54.5 years, with 80.2% of the AML group being female. The median tumor size was 50.2 mm. The AML group had larger tumor diameters (50.2 mm vs 34.9 mm) but shallower depths (16.1 mm vs 21.7 mm). Median R.E.N.A.L and PADUA scores were 6.5 and 8.2, respectively, with a median EBL of 128.2 mL. Blood transfusion was required in 15.5% of cases. Tumor diameter, depth, R.E.N.A.L score, and PADUA score significantly correlated with EBL, while BMI, tumor diameter, and R.E.N.A.L score correlated with blood transfusion. The AUCs for predicting EBL and blood transfusion were 0.778 and 0.771 for tumor diameter, and 0.661 and 0.711 for R.E.N.A.L score.

Conclusion: RAPN might be a safe option for RAML, with tumor diameter being the most accurate predictor of EBL and blood transfusion. These findings can improve preoperative assessments and surgical planning.

Keywords: robotic-assisted partial nephrectomy, hemorrhagic complication, tumor diameter, tumor depth, nephrometry

Introduction

Renal angiomyolipoma (AML) stands out as an infrequent benign neoplasm within the kidney, characterized by a unique composition of blood vessels, smooth muscle, and adipose tissue.[1] Unlike oncocytoma or renal cell carcinoma (RCC), AML tends to manifest more frequently in women around the age of 50, and surgically treated cases often present with larger average sizes.[2] Although many AML cases remain asymptomatic, proactive management becomes essential in instances of persistent pain or acute bleeding episodes, particularly in female patients of childbearing age or those with large tumors as outlined by the 2020 European Association of Urology guidelines.[3,4]

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Management strategies for AML encompass arterial embolization or partial nephrectomy. While partial nephrectomy currently stands as the standard treatment for small malignant tumors due to its comparable cancer control and superior preservation of renal function compared to radical nephrectomy, the optimal management approach for AML, be it arterial embolization[5] or nephron-sparing surgery, remains a subject of controversy. Although arterial embolization appears less invasive than partial nephrectomy and seems to reduce AML volume, it necessitates secondary treatment in 30% of cases.[6]

In terms of the surgical technique for partial nephrectomy in AML, unlike RCC where a larger resection surface is required for achieving R0 resection, tumor enucleation (TE) emerges as a viable and effective option. TE maximizes glomerular preservation and minimizes intra- and postoperative complications.[7] Moreover, with technological advancements, robotic-assisted partial nephrectomy (RAPN) is increasingly preferred over traditional or laparoscopic methods, offering benefits such as reduced estimated blood loss (EBL) and excellent functional preservation.[8–11] Various studies have indicated the safety and efficacy of adopting nephrometry scores such as the Preoperative Aspects and Dimensions Used for An Anatomic (PADUA score), R.E.N.A.L score, and Simplifire PADUA score (SPARE) to predict surgical outcomes of RAPN for AML.[11,12]

Despite existing research on risk factors for bleeding complications in RAPN, both in AML and non-AML tumors,[13] the unique features of AML warrant dedicated exploration. In this study, we aim to identify specific risk factors influencing estimated blood loss (EBL) and the need for blood transfusions in patients undergoing RAPN for AML.

Materials and Methods

Patients

A retrospective analysis was conducted on data obtained from our hospital's surgical database, encompassing patients who opted for robotic-assisted partial nephrectomy (RAPN) after comprehensive discussions with surgeons. The study period spanned from May 2019 to June 2023, including patients with confirmed pathologies of either renal AML or non-AMLs. The study received approval from the Institutional Review Board of Chang Gung Memorial Hospital. Informed consent requirements were waived by the board due to the retrospective design of the study. After data retrieval, we ensured privacy through dissociation methods, and the subsequent analysis and storage are conducted on a non-networked computer that is also dissociation. Patient characteristics were thoroughly documented, encompassing variables such as height, weight, gender, body mass index, anticoagulant medication, and tumor features (size, depth, location, R.E.N.A.L. Nephrometry score, PADUA Nephrometry score, and final pathological report). Surgical details, including preoperative parameters (hemoglobin level, platelet counts), intraoperative factors (operative time, warm ischemia time, estimated blood loss (EBL)), and postoperative outcomes (change in hemoglobin level, postoperative complications, hospital stay, J-P drain days, blood transfusion), were meticulously analyzed. The largest diameter and depth of tumors within the kidney parenchyma were determined based on CT scans, with image analysis performed by an independent radiologist, ensuring objectivity. Nephrometry scores were calculated using preoperative imaging studies, and this process was conducted consistently by the same reviewer.

Outcome Measure and Statistical Analysis

Descriptive analyses were presented for patient demographics and operative-related parameters. Group differences between AML and non-AML cohorts were assessed using independent t-tests. All statistical tests were two-tailed, and significance was considered at $P < 0.05$. Predictors for EBL and blood transfusion were determined through Pearson correlation tests and independent t-tests. Linear regression was employed for multivariate analysis. To explore risk factors for blood transfusion and EBL, independent t-tests and chi-square tests were initially conducted, followed by multivariate analysis using binary regression. Receiver Operating Characteristic (ROC) curves and Area Under the Curve (AUC) calculations were utilized to investigate potential predictors for blood transfusion and EBL ≥ 200mL. The entire statistical analysis was carried out using IBM SPSS Statistics (version 22).

Results

A total of 255 patients diagnosed with renal tumors underwent RAPN for tumor excision [Figure 1]. Among these tumors, 27.3% were identified as AML, while 60.4% were RCC. In the AML group, the mean age was 54.5 years, with females accounting for 80.3%. The average RENAL and PADUA scores were 6.5 and 8.2, respectively. The mean tumor diameter was 50.2 mm, and the mean tumor depth was 16.1 mm. During RAPN, the mean EBL was 128.2 ± 163 mL, with a median ischemia time of 25.7 minutes. Peri-operative blood transfusions were received by 15.5% of patients, and one patient required embolization post-RAPN. Major complications occurred in 1.4% of cases. Further detailed general and surgery-related characteristics are presented in Table 1.

The comparison between the AML and non-AML groups is outlined in Table 2. A higher proportion of females (80.3%) was observed in the AML group, while the non-AML group had a male predominance (62.5%). Significant differences were noted in tumor statistics, with the AML group exhibiting a mean tumor diameter of 50.2 mm and mean depth of 16.1 mm, compared to the non-AML group with separate values of 34.9 mm and 21.7 mm. Nephrometry scores also showed statistically significant differences (mean RENAL score: AML 6.5, non-AML 7.2, $P<0.05$). Comprehensive general and surgery-related data are presented in Table 2.

In the risk factor analysis for EBL, tumor diameter, tumor depth, RENAL score, and PADUA score emerged as significant predictors in univariate analysis. However, in multivariate analysis, only the PADUA score retained significant correlation with EBL (p-value = 0.027), as detailed in Table 3.

Regarding the risk factor analysis for blood transfusion, BMI, tumor diameter, and RENAL score were identified as significant predictors in univariate analysis. And only BMI retained significant correlation with blood transfusion in multivariate analysis. Detailed results are presented in Table 4.

In ROC curve analysis for EBL>200mL, tumor diameter exhibited the highest Area Under the Curve (AUC) compared to PADUA score, tumor depth, and RENAL score (0.778 vs 0.699, 0.667, and 0.661, respectively). Similarly, in the ROC curve for blood transfusion, tumor diameter maintained the highest AUC (0.731), surpassing RENAL score, tumor depth, and PADUA score (0.711, 0.707, and 0.692, respectively). These results are visually represented in [Figure 2].

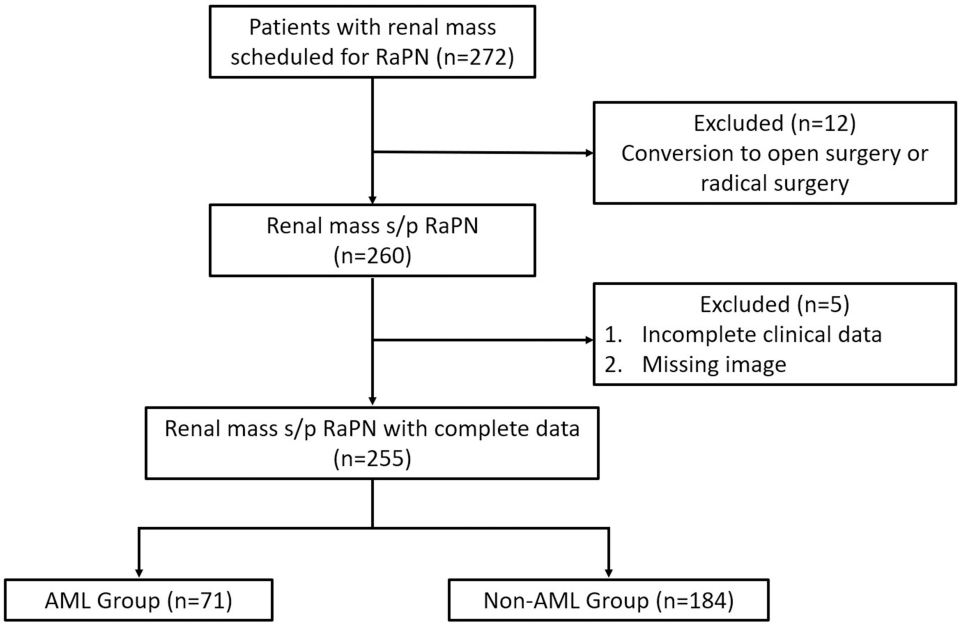

Figure 1 Flowchart.

Table 1 Patients' General Characteristics

Variables	Mean/Number	SD	Range/Percentage	
Total Number	71			
Age	54.5	12.8	26–77	Year-old
Gender				
Female	57		80.3%	
Male	14		19.7%	
Height	159.3	7.8	147–177	cm
Weight	64.8	13.7	45–104	Kilograms
BMI	25.5	4.6	18.4–38.3	kg/cm^2
Anticoagulant				
Yes	1		1.4%	
No	70		98.6%	
Pre-OP platelet count	248.0	64.7	81–406	1000/uL
Pre-OP Hb	13.2	1.7	8.1–17.3	g/dL
Tumor Related Parameters				
Tumor Diameter	50.2	26.3	10.1–151.4	mm
Tumor depth	16.1	9.0	1.0–45.7	mm
R.E.N.A.L score	6.5	1.7	4–10	
PADUA score	8.2	1.4	6–13	
Location				
Anterior	30		42.3%	
Posterior	41		57.7%	
Surgery Related Parameters				
Post-OP Hb	12	1.4	7.9–15.0	g/dL
Post-OP Hb change	−1.3	1.0	−4.3–0.9	g/dL
Ischemic time	25.7	18.5	0–116	mins
Estimated blood loss	128.2	163	0–800	mL
J-P drain days	4.0	1.5	2–10	days
Hospital stay	4.5	1.6	3–12	days
Blood transfusion				
Yes	11		15.5%	
No	60		84.5%	
Embolization				
Yes	1		1.4%	
No	70		98.6%	
2^{nd} surgery				
Yes	0		0.0%	
No	71		100.0%	
Major complication				
Yes	1		1.4%	
No	70		98.6%	

Abbreviations: BMI, Body Mass Index; AML, angiomyolipoma; Hb, Hemoglobin.

Discussion

RAPN is increasingly favored for renal mass removal, offering benefits over traditional open or laparoscopic surgeries, such as shorter hospital stays, less blood loss, faster recovery, and reduced postoperative pain. Studies by Guerrero et al and Bray et al[14,15] found that RAPN led to reduced warm ischemia time and better renal function preservation. For localized renal cancer (T1 or T2 tumors), partial nephrectomy is the standard treatment. Pierorazio et al[16] showed that while various strategies yield similar cancer-specific survival rates, radical nephrectomy results in the greatest decline in

Table 2 Difference Analysis in Non-AML and AML Group

	Non-AML Group (N=184)	AML Group (N=71)	Univariate Analysis *p* value
Age	56.3±13.9	54.5±12.8	0.359
Gender			
Female	69	57	<0.001
Male	115	14	
Height	163.9±9.4	159.3±7.8	<0.001
Weight	70.5±14.4	64.8±13.7	0.005
BMI	26.1±4.0	25.5±4.6	0.313
Tumor diameter	34.9±13.0	50.2±26.3	<0.001
Tumor depth	21.7±8.8	16.1±9.0	<0.001
RENAL	7.2±1.5	6.5±1.7	0.001
PADUA	8.5±1.4	8.2±4.1	0.074
AP			
A	108	30	0.018
P	76	41	
Pre-OP platelet	247.9±88.4	248.0±64.7	0.995
Pre-OP Hb	13.8±1.7	13.2±1.7	0.012
Bleeding Related Events			
Ischemia time	31.3±24.6	25.7±18.5	0.097
Estimated blood loss	155.2±231.0	128.2±163.0	0.369
Post-OP Hb change	−1.41±1.1	−1.26±1.0	0.030
J-P drain days	4.8±3.0	4.0±1.5	0.026
Hospital stay	5.3±5.4	4.5±1.6	0.212
Blood transfusion			
Yes	22	11	0.451
No	162	60	
Embolization			
Yes	3	1	0.898
No	181	70	
2nd surgery			
Yes	3	0	0.279
No	181	71	
Major complication			
Yes	8	1	0.254
No	176	70	

Notes: **p* value< 0.05; ** *p* value< 0.01.

Table 3 Risk Factors for EBL of AML During RaPN

	Univariate Analysis		Multi-Variate Analysis	
	Pearson Correlation / Mean	*p* value	Beta	*p* value
Age	0.066	0.583		
BMI	0.033	0.783		
Tumor diameter	0.396	0.001	0.236	0.071
Tumor depth	0.322	0.006	0.070	0.668
RENAL	0.357	0.002	0.016	0.932

(*Continued*)

Table 3 (Continued).

	Univariate Analysis		Multi-Variate Analysis	
	Pearson Correlation / Mean	*p* value	Beta	*p* value
PADUA	0.421	<0.001	0.291	0.027
Platelet	(0.019)	0.878		
Gender				
Female	115.4±159.9	0.181		
Male	180.7±182.6			
AP				
A	101.5±107.9	0.240		
P	147.8±192.7			
Anticoagulant				
No	129.4±163.9	0.632		
Yes	50.000			

Notes: *p value< 0.05, **p value<0.01.
Abbreviation: EBL, Estimated blood loss.

Table 4 Risk Factors Analysis for Blood Transfusion

	No Blood Transfusion Group	Blood Transfusion Group	Univariate Analysis	Multi-Variate Analysis	
	Mean±SD	Mean±SD	*p* value	Beta	*p* value
Age	53.7±13.1	58.6±10.1	0.247		
BMI	25.9±4.7	23.0±3.2	0.047*	0.823	0.049*
Tumor diameter	47.4±27.1	64.9±15.7	0.042*	1.026	0.058
Tumor depth	15.4±9.3	20.1±5.9	0.115		
RENAL	6.3±1.7	7.4±1.1	0.048*	1.358	0.186
PADUA	8.1±1.5	8.7±0.9	0.171		
Platelet	251.2±63.6	230.8±71.1	0.342		
AP					
A	25	5	0.815		
P	35	6			
Gender					
Female	47	10	0.335		
Male	13	1			
Anticoagulant					
No	59	11	0.666		
Yes	1	0			

Notes: *p value< 0.05, **p value<0.01.

renal function and higher chronic kidney disease rates. However, when it comes to AML, the management of symptomatic tumors remains a subject of controversy.

In our study, we elucidated the complications related to RAPN for AML. Bleeding-related events, such as perioperative blood transfusion, postoperative embolization, the necessity for a second surgery, and major complications, were infrequent. The major complication rate stood at 1.4%, with only one out of seventy-one cases requiring further embolization post-operation. From a statistical standpoint, our study suggests that RAPN is a safe and effective procedure for the treatment of symptomatic AML.[17]

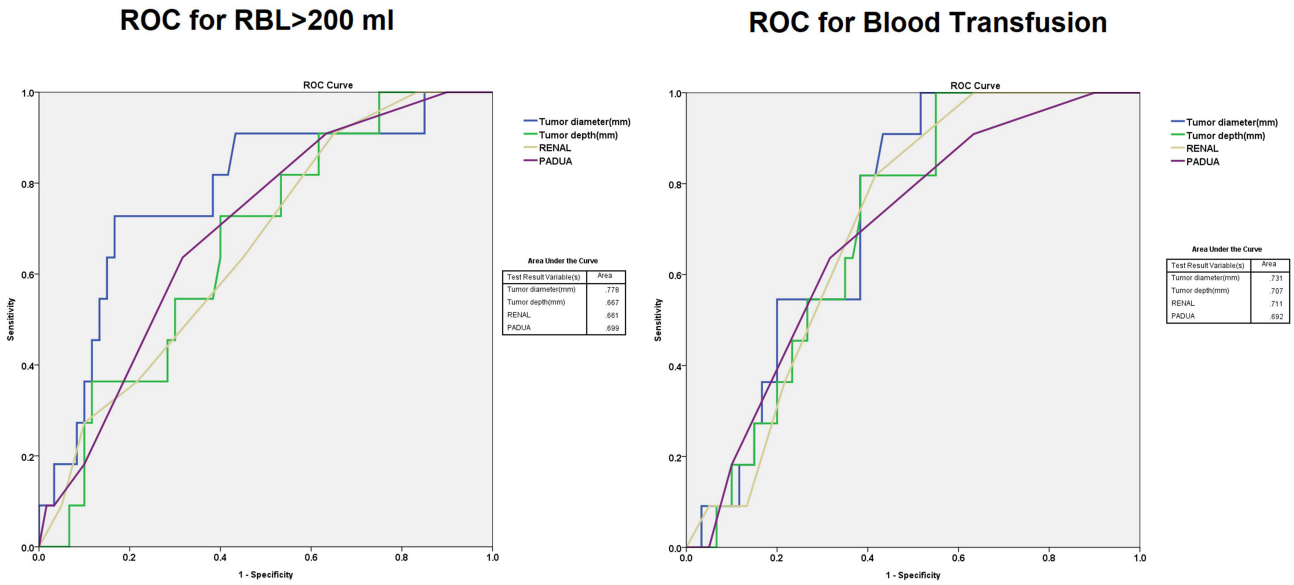

Figure 2 ROC for EBL and blood transfusion.

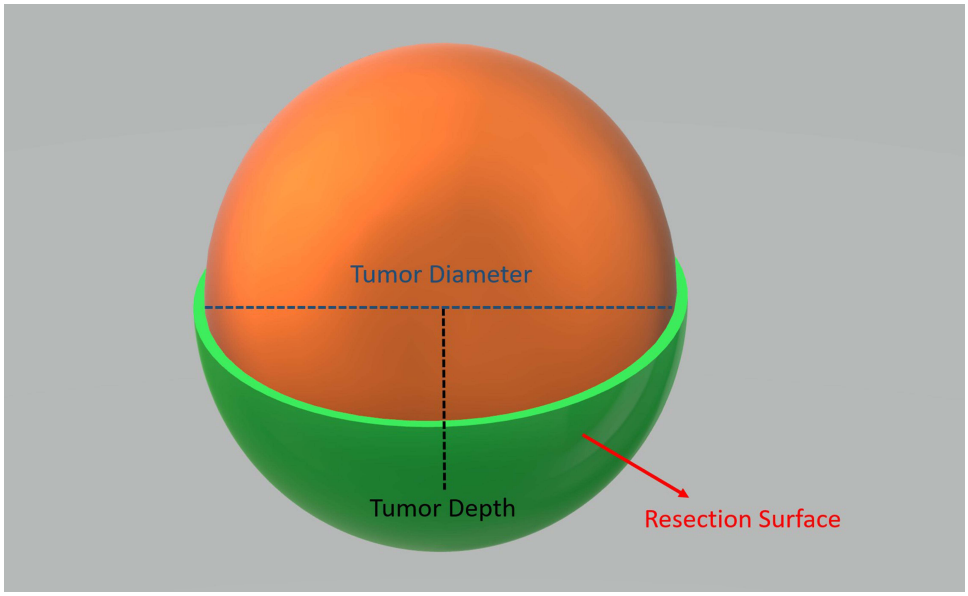

Figure 3 Tumor enucleation.

Previous studies have highlighted the advantages of RAPN for renal masses.[18,19] In our study, we aimed to take a step further by distinguishing and comparing operation-related parameters between AML and non-AML groups undergoing RAPN. Notably, the AML group exhibited larger but shallower tumors compared to the non-AML group, suggesting that AMLs are larger yet less invasive to renal parenchyma. Given these differences, RCC typically requires the removal of more renal tissue to achieve R0 resection [Figure 3]. For example, Henderickx et al[20] demonstrated that a positive surgical margin is associated with a higher risk of local recurrence in pT1 RCC undergoing partial nephrectomy. In contrast, AMLs, being benign neoplasms and usually non-invasive, do not necessitate the consideration of surgical margins. Consequently, tumor enucleation [Figure 3] becomes the predominant method for AML removal during RAPN. This discrepancy prompted us to investigate whether nephrometry indices, including R.E.N.A.L. score and PADUA

score, commonly used to predict surgical-related risks in RCC undergoing traditional or laparoscopic partial nephrectomy, are equally effective in the context of RAPN.

In our study, we aimed to identify factors that predict bleeding during robotic-assisted partial nephrectomy (RAPN). We found several significant predictors of estimated blood loss, including tumor diameter, tumor depth, RENAL score, and PADUA score. Tumor diameter had the strongest predictive value.

Our analysis showed that larger tumor diameters lead to more extensive kidney tissue removal, which can increase blood loss. This aligns with findings from Weprin et al, who used a modified PADUA score to predict complications. The original PADUA score was designed for open surgeries, but with RAPN, the surgical area is less of a constraint, allowing for more precise incisions.

We also examined risk factors for blood transfusion and found that tumor diameter, body mass index (BMI), and RENAL score were significant. Interestingly, lower BMI was linked to a higher risk of needing a blood transfusion, likely due to lower overall blood volume, which can make vital signs more sensitive to blood loss. However, this increased risk did not lead to a higher complication rate.

Overall, our findings suggest that tumor diameter is the best predictor for blood loss and transfusions during RAPN. We recommend using it as a simple tool for anticipating these risks, especially in patients with larger tumors and lower BMI, to ensure adequate preparation for potential blood transfusions.

While our study provides valuable insights, there are notable limitations. Firstly, the retrospective design may introduce biases. Secondly, despite being collected from a single center, operations were performed by multiple surgeons, potentially introducing patient selection bias. Thirdly, although tumor characteristics showed statistical significance in univariate analysis for estimated blood loss and blood transfusion, only the PADUA score remained a significant predictor in multivariate analysis. This suggests that each tumor characteristic may not be independent of other factors. Fourth, the sample size is relatively small, which could affect the study power. Further studies are expected to extend the sample size. Our study primarily focused on exploring the relationship between tumor characteristics and bleeding-related events, and further research is essential to investigate their correlation with the preservation of renal function in these patients.

On the other hand, purely off-clamp robotic partial nephrectomy has proven to be a feasible and safe surgical approach compared to the on-clamp strategy. Gabriele Tuderti et al[21,22] stated that even in cases of totally endophytic renal tumors or tumors with a RENAL score of 9 or higher, off-clamp robotic partial nephrectomy resulted in a favorable rate of perioperative complications. Giuseppe Simone et al shared a similar perspective.[23] In our study, the angiomyolipoma (AML) group had larger but shallower tumors, indicating that they were more exophytic. Theoretically, the off-clamp approach may be more suitable for AML. However, although some cases in our database involved the off-clamp method for RAPN, we did not analyze this data individually. Further studies are needed to explore this topic in more detail.

Conclusion

In conclusion, RAPN emerges as a safe and viable surgical technique for the treatment of AML, demonstrating a lower risk of perioperative complications. Notably, bleeding-related events stand out among the risk factors, with tumor diameter might be the most accurate predictor for estimating both blood loss and the need for blood transfusion in AML cases undergoing RAPN. This highlights the significance of considering tumor characteristics, particularly diameter, in preoperative assessments and preparation strategies to enhance the overall safety and effectiveness of RAPN for AML treatment.

Abbreviations

RCC, renal cell carcinoma; RAPN, robotic-assisted partial nephrectomy.; HC, hemorrhagic complication; CKD, chronic kidney disease; AML, angiomyolipoma; WIT, warm ischemia time; HB, Hemoglobin.

Data Sharing Statement

All data generated or analyzed during this study are included in this published article.

Ethics Approval and Consent to Participate

This study has been conducted in accordance with the ethical principles mentioned in the Declaration of Helsinki (2013). This study was approved by Chang Gung Medical Foundation Institutional Review Board. (IRB Number: 202101497A0C602).

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Manuscript writing: I-Hung Shao, Ming-Chien Chen.

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no competing interests.

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