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From sutureless to standard: a comprehensive analysis of conversion rates in laparoscopic partial nephrectomy

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Abstract

Objective To assess the rate at which sutureless partial nephrectomy (SLPN) transitions to standard partial nephrectomy (SPN), focusing on preoperative factors that might prompt such conversions.

Patients and methods In this retrospective study, we analyzed the efficacy of SLPN performed on adults at our institution from 2016 to 2023. The subjects were patients diagnosed with localized solid renal tumors. The primary technique employed was resection with scissors and argon beam coagulation for hemostasis, with suturing techniques used only when necessary. Predictive factors necessitating conversion to SPN were identified, and the associations among multiple variables were explored using various statistical analysis methods, including logistic regression, to identify key preoperative predictive factors.

Results Our institution performed 353 SLPN, with 21 cases (5.9%) necessitating conversion to SPN. The conversion rates for the Laparoscopic Partial Nephrectomy (LPN) subgroup and the Robotic-assist Partial Nephrectomy (RPN) subgroup were 7.9% (17/215) and 2.9% (4/138), respectively, nearing statistical significance ($P = .066$). Significant differences were observed between the conversion group and the no conversion group in terms of preoperative estimated Glomerular Filtration Rate (eGFR), age at surgery, tumor size, and exophytic/endophytic characteristics. Multivariate analysis identified age at surgery, preoperative eGFR, radiological tumor size, and tumor exophytic/endophytic nature as significant predictors for conversion to SPN.

Conclusion This investigation highlights the efficacy and feasibility of SLPN while identifying critical factors influencing the necessity for conversion to SPN. The identified predictors, including younger surgical age, superior preoperative eGFR, and specific tumor characteristics, provide valuable insights for refining surgical strategies.

Keywords Partial nephrectomy, Renal cell carcinoma, Suture, Sutureless

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Introduction

Renal Cell Carcinoma (RCC), primarily the clear cell subtype, represents 2-3% of adult malignancies, with a 2% annual increase in incidence, posing a significant public health challenge [1]. Technological advances in ultrasound and CT scans have significantly boosted the detection of renal tumors, particularly smaller lesions, leading to a shift towards nephron-sparing strategies [2]. Partial Nephrectomy (PN) has become the preferred treatment for renal masses ≤ 7 cm, especially beneficial for patients with preexisting chronic kidney conditions, as it reduces the risk of chronic renal insufficiency and cardiovascular mortality [3, 4].

Sutureless Partial Nephrectomy (SLPN) leverages cutting-edge surgical technologies, including hemostatic agents and sealants, to achieve optimal hemostasis and parenchymal reconstruction without traditional sutures [5, 6]. This innovative approach aims to reduce warm ischemia time (WIT), minimize blood loss, and potentially hasten postoperative recovery, thereby lowering the risk of complications such as parenchymal damage and pseudoaneurysms [7–9].

SLPN has numerous advantages and potential, and the transition to Standard Partial Nephrectomy (SPN) remains infrequent. However, the scarcity of comprehensive data on the incidence of such conversions, their underlying reasons, and the patient and tumor characteristics that increase the risk highlights the need for further investigation. Understanding these factors is essential for improving surgical planning and patient counseling, ultimately enhancing the safety and efficacy of renal surgeries.

Our research focuses on determining the frequency of conversions from SLPN to SPN in our institution and analyzing the preoperative factors associated with these conversions to better guide clinical decisions.

Patients and methods

This study conducted a comprehensive investigation into the application of SLPN on patients aged 18 and above from 2016 to 2023. The patient cohort, selected based on the presence of clinically localized solid renal masses ≤ 4 cm in diameter, underwent a thorough preoperative imaging review by a specialized uro-oncologist to assign RENAL nephrometry scores, considering factors such as tumor size, exophytic/endophytic properties, and location.

The surgical procedures were performed by two experienced surgeons specializing in SPN. They opted for either Laparoscopic Partial Nephrectomy (LPN) or Robotic-assisted Partial Nephrectomy (RPN) based on personal preference. Multiple trocars were utilized to establish the surgical pathway and create pneumoperitoneum. Gerota's fascia and the surrounding adipose tissue were meticulously incised relative to the tumor's position to ensure full mobilization of the kidney, allowing optimal tumor exposure.

In each procedure, the renal artery was temporarily occluded using a vascular clamp, and the tumor was excised with scissors, primarily through enucleation or enucleoresection. Any visible blood vessels were clipped using Hem-o-lok clips. The tumor bed was treated with an argon beam coagulator (ABC) until a coagulation eschar formed and bleeding ceased. Following this, the vascular clamp was released. If bleeding persisted despite coagulation, immediate suturing of one or more layers was performed to ensure hemostasis.

Participants were stratified into two categories to distinguish those requiring conversion to SPN. Comparative analyses of demographic and tumor-specific attributes were conducted to elucidate factors predisposing to surgical conversion.

Statistical analyses employed median and Interquartile Range (IQR) for continuous variables, and frequencies with percentages for categorical ones, utilizing the Wilcoxon rank-sum and Chi-square/Fisher's exact tests accordingly. A logistic regression model with backward selection was adopted to explore multivariate associations, presenting results as odds ratios with 95% confidence intervals, ensuring rigorous variable selection criteria to mitigate overfitting. Statistical analyses were performed using version 26.0 of the SPSS software package (SPSS Inc., Chicago, IL, USA).

Results

From 2016 to 2023, our institution documented a total of 353 SLPN procedures, with 21 instances (5.9%) necessitating a transition to SPN. Delving into specifics, within the LPN subgroup, there were 17 conversions out of 215 cases (7.9%, 95% Confidence Interval [CI] 4.3–11.5) to SPN, while the RPN subgroup saw 4 conversions out of 138 cases (2.9%, 95% CI 0.1–5.7), $P=.066$. Intriguingly, the overall conversion rate exhibited a marginal decline throughout the study, descending from an initial 8.0–6.0%, but this change did not reach statistical significance ($P=.726$) (Fig. 1).

Table 1 encapsulates the demographic profiles and tumor characteristics of both the no conversion and conversion groups. The conversion group demonstrated a notably younger median age at the time of surgery (58.0 years [IQR: 55.0–72.0] as opposed to 64.0 years [IQR: 59.0–72.0] in the no conversion group, $P=.007$) and a superior preoperative Estimated Glomerular Filtration Rate (eGFR) with a median of 66.4 [IQR: 62.6-88.19] compared to 57.5 [IQR: 49.4–73.3] mL/min/1.73 m^2 in the conversion group, ($P=.001$). No significant disparities were observed in terms of gender, Body Mass Index (BMI), Charlson Comorbidity Index (CCI), American

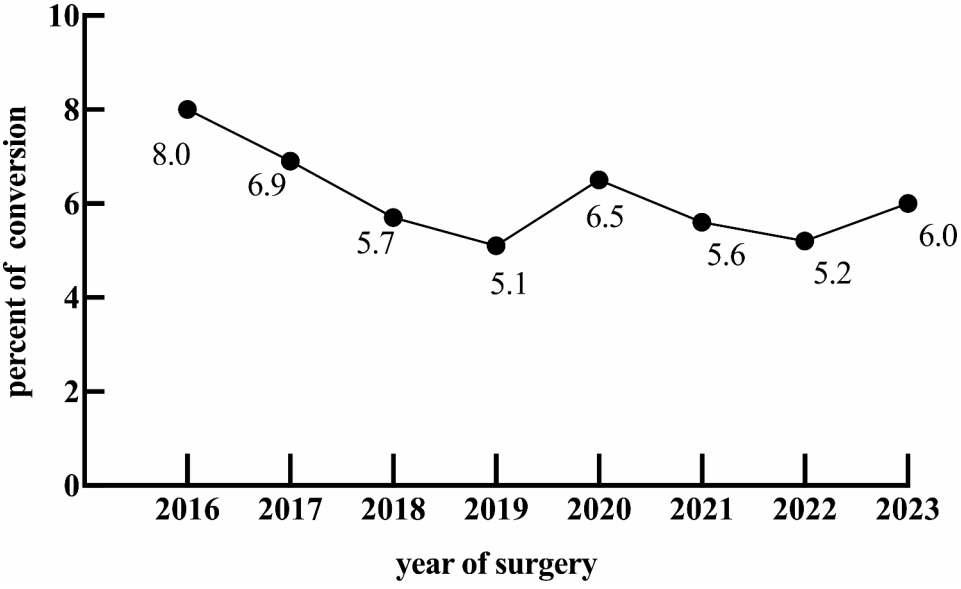

Fig. 1 Rates of conversions from SLPN to SPN between 2016 and 2023

Society of Anesthesiologists (ASA) score, and histopathological findings. The tumor characteristics such as the proximity to the collecting system, anterior versus posterior location, and the RENAL nephrometry score were comparable. However, notable distinctions were made in the radiological dimensions of the tumors (26.0 mm [IQR: 22.0–30.0] in conversion group versus 31.0 mm [IQR: 29.0–35.0] in no conversion group, $P=.001$) and the exophytic/endophytic properties of the tumors ($P=.036$), highlighting significant differences.

Intraoperative features are contrasted in Table 2. The group undergoing conversion to SPN exhibited a heightened median estimated blood loss (EBL) (91 mL [IQR: 57–195] versus 77 mL [IQR: 48–100] in the no conversion group, $P=.039$) alongside an elongated duration of surgery (125 min [IQR: 102–182] compared to 109 min [IQR: 97–123], $P=.021$). The WIT remained consistent across groups (17 min [IQR: 13–19] for the conversion group versus 16 min [IQR: 14–19] for the no conversion group, $P=.725$), with no significant correlation between the surgical approach (LPN or RPN) and the likelihood of conversion ($P=.284$).

Multivariate analysis pinpointed pivotal predictors for conversion, encompassing the patient's age at the time of surgery (Odds Ratio [OR]: 0.087 [95% CI: 0.018–0.420], $P=.002$); preoperative eGFR (OR: 86.118 [95% CI: 14.192-522.561], $P<.001$); radiological tumor size (OR: 92.608 [95% CI: 12.397-691.779], $P<.001$); and the tumor's exophytic/endophytic nature (OR: 32.525 [95% CI: 5.719-184.987], $P<.001$).

Discussion

The goal of PN is complete tumor excision with negative margins, maximal functional preservation, and avoidance of complications. Resection and reconstruction techniques significantly affect the amount of vascularized parenchyma preserved, which represents a major determinant of ultimate renal function [10]. Vascularized parenchymal volume can be lost during traditional PN in two ways: excised parenchymal volume or devascularized parenchymal volume, which is the preserved parenchymal volume that becomes devascularized during kidney reconstruction [11].

Recent studies indicate that in the current era of minimal margin or enucleative PN, the excised parenchymal volume tends to be minimal in most patients [12], whereas the devascularized parenchymal volume is considerably more significant. Traditional renal suturing reconstruction methods can inadvertently damage small renal arteries and veins, leading to the loss of function in some preserved renal units and potentially impacting the patient's long-term renal function. The sutureless technique significantly minimizes devascularization caused by suturing, which is essential for preserving renal function. This key advantage positions it as a focal point for advancements in PN techniques, promising to enhance postoperative renal recovery. Sutureless techniques involve using coagulation or hemostatic agents as substitutes for renorrhaphy, thereby avoiding the traditional suturing process.

Wu et al. implemented monopolar electrocoagulation for LPN, demonstrating its safety and feasibility for renal tumors < 3 cm [13]. Similarly, Khoder and Loertzer reported satisfactory outcomes using a thulium laser for

Table 1 Patient and tumor characteristics

	No Conversion ***N*** **= 332**	**Conversion** ***N*** **= 21**	***P***
Age at surgery (y), Median (IQR)	64.0 (59.0–72.0)	58.0 (55.0–72.0)	0.007
Number of males, n (%)	208 (62.7)	11 (52.4)	0.347
Body mass index (kg/m2), Median (IQR)	28.0 (25.9–31.5)	29.1 (26.0-32.9)	0.363
Preoperative eGFR (mL/min/1.73 m2), Median (IQR)	57.5 (49.4–73.3)	66.4 (62.6–88.1)	0.001
CCI, Median (IQR)	1.0 (1.0–3.0)	1.0 (1.0–3.0	0.941
ASA score, Median (IQR)	2.0 (1.0–3.0)	2.0 (1.0–2.0)	0.461
Radiographic tumor size(mm), Median (IQR)	26.0 (22.0–30.0)	31.0 (29.0–35.0)	0.001
RENAL-NS, n (%)			
Low: 4–6	203 (61.1)	12 (57.1)	0.716
Medium: 7–9	129 (38.9)	9 (42.9)	
RENAL-NS components, n (%)			
Exophytic/endophytic properties (E)			
>50% exophytic	173 (52.1)	6 (28.6)	0.036
<50% exophytic	159 (47.9)	15 (71.4)	
Nearness to collecting system in mm (N)			
>=7	96 (28.9)	1 (4.8)	0.056
>4 but < 7	47 (14.2)	4 (19.0)	
<=4	189 (56.9)	16 (76.2)	
Anterior/posterior (A)			
Anterior	146 (44.0)	5 (23.8)	0.148
Posterior	97 (29.2)	7 (33.3)	
Middle (X)	89 (26.8)	9 (42.9)	
Location relative to polar lines (L)			
Entirely polar	126 (38.0)	5 (23.8)	0.215
Crosses polar line	100 (30.1)	10 (47.6)	
Entirely between polar lines	106 (31.9)	6 (28.6)	
Histopathology, n (%)			
Clear cell	252 (75.9)	15 (71.4)	0.918
Papillary	40 (12.0)	3 (14.3)	
Chromophobe	4 (1.2)	0 (0)	
Other malignant	3 (0.9)	0 (0)	
Benign	33 (9.9)	3 (14.3)	

Table 2 Intraoperative characteristics

	No Conversion ***N*** **= 332**	**Conversion** ***N*** **= 21**	***P***
Procedure type, n (%)			
LPN	198 (59.6)	15 (71.4)	0.284
RPN	134 (40.4)	6 (28.6)	
Estimated blood loss (mL), Median (IQR)	77 (48–100)	91 (57–195)	0.039
Operative time (min), Median (IQR)	109 (97–123)	125 (102–182)	0.021
Warm ischemia time (min), Median (IQR)	17 (13–19)	16 (14–19)	0.725

PN [14, 15]. Kayhan et al. conducted a retrospective analysis of 170 patients who underwent partial nephrectomy (PN) using either ABC or traditional suturing techniques, confirming the short-term efficacy of ABC and its safety and stability in long-term follow-up [5].

During the period from 2016 to 2023, our study showed a conversion rate of 5.9% in SLPN procedures, with 21 out of 353 surgeries transitioning to SPN. Notably, the LPN subgroup exhibited a higher conversion rate of 7.9% (17/215), compared to a lower rate of 2.9% (4/138) in the RPN subgroup, although not reaching statistical significance with $P=.066$. This variation aligns with the findings of Jeffrey J. Leow et al. who reported a decreased likelihood of conversion in RPN procedures [16]. Studies by Choi JE et al. and Pavan N et al. further corroborate the perioperative advantages of robotic-assisted surgeries [17, 18].

Contrary to expectations and trends reported in the literature, our study did not observe a significant decrease in conversion rates over the study period, with rates slightly declining from 8.0 to 6.0%, (P=.726). This finding may imply that factors other than technological advancements and surgical experience may play a crucial role in determining the likelihood of conversion, such as demographic and tumor characteristics. The stable conversion rates observed in our study also indirectly emphasize the low learning threshold of the sutureless technique, which seems to be unrelated to the surgeon's experience. This may be due to the intuitive operation process and fewer steps involved in the sutureless technique, thereby reducing the time and experience required to learn and master it [5, 6]. A recent video article detailed the surgical techniques and outcomes of the first 11 cases performed by a young surgeon at the start of his experience with RPN. Bleeding emerging from the resection bed was effectively managed using bipolar coagulation while meticulously following the enucleation plane [19].Therefore, the ease of learning the sutureless technique could contribute to its rapid adoption and application, which is important for improving medical efficiency and patient outcomes.

Although literature reports suggest that the likelihood of converting from partial nephrectomy to radical nephrectomy increases with age [20], our observations indicate a contrasting trend when employing sutureless techniques for managing the bleeding site post-renal partial nephrectomy. We noted that the age of patients in the conversion group was generally lower than that in the no conversion group. Younger patients typically have healthier kidneys with more robust blood flow. This enhanced vascularity may lead to increased bleeding during the excision of renal tumors [21].

When surgeons opt for sutureless techniques, which are less invasive and aim to preserve renal function, managing significant bleeding can pose a greater challenge. The higher the renal blood flow, the more difficult it may be to achieve effective hemostasis using these minimally invasive methods. Consequently, this might necessitate a shift to more traditional sutured techniques that offer better control of bleeding.

EGFR is a critical indicator for assessing renal function in partial nephrectomy. Takagi et al. highlighted the importance of selecting surgical methods for renal tumors in robot-assisted laparoscopic partial nephrectomy, particularly the guiding role of preoperative eGFR in the decision-making process [22]. This indicator is essential for evaluating a patient's ability to endure surgery and recover renal function postoperatively. In clinical practice, the decision to perform partial nephrectomy and the extent of resection are often directly influenced by preoperative eGFR. Ni and Yang demonstrated the significant role of preoperative eGFR in predicting postoperative renal function when comparing robot-assisted with open partial nephrectomy in patients with clinical T1 stage renal cell carcinoma [23].

However, in our study, the preoperative eGFR of patients in the conversion group was significantly higher than that in the no conversion group. Younger patients typically have higher eGFR, indicating better renal blood supply. However, this improved blood supply may increase the risk of intraoperative bleeding in partial nephrectomy using a sutureless technique. Although the sutureless technique offers the advantage of being minimally invasive, controlling bleeding and maintaining a clear surgical field can be more challenging in cases of significant bleeding. A higher eGFR may require surgeons to be more cautious in their surgical planning, considering the potential risks of uncontrollable bleeding associated with the sutureless technique.

Similarly, our study found that the average size of tumors in patients who converted to traditional suturing during partial nephrectomy was significantly larger (31.0 vs. 26.0 mm, P=.001) compared to those who did not require conversion, and the proportion of tumors with endophytic growth was also higher (P=.036).

First, larger or endophytically growing renal tumors are often more closely intertwined with critical structures such as renal blood vessels, the ureter, and the renal pelvis [24]. This proximity makes it particularly important to repair these structures with traditional suturing techniques after damage during surgery, which is difficult to achieve with generally less invasive sutureless techniques. Studies have shown that partial nephrectomy for large or endophytic tumors involves longer operative times and a higher risk of surgical complications compared to radical nephrectomy [25–27].

Secondly, the complexity of blood supply to larger and deeper tumors increases the surgical challenge. These tumors typically have a more intricate vascular network, making intraoperative hemostasis more difficult and increasing the risk of accidental damage to surrounding vessels [28]. The literature further emphasizes the need for effective bleeding control in these scenarios, using more controllable suturing methods.

The multivariate analysis identified key factors influencing the likelihood of surgical conversion during partial nephrectomy. These key factors include younger surgical age, higher preoperative eGFR, larger tumor size, and endophytic tumor characteristics. These findings suggest that younger patients, especially those with larger, complex tumors, particularly endophytic tumors, are more prone to surgical conversion.

For larger renal tumors, especially those with complex anatomical features such as endophytic growth, an increased incidence of surgical conversion during partial nephrectomy is supported by various studies in the field.

These studies identified key factors leading to the decision to switch from less invasive, nephron-sparing surgical approaches to more traditional surgical techniques.

Research from the Michigan Urological Surgery Improvement Collaborative (MUSIC) and another study highlighted factors influencing the conversion from robotic partial nephrectomy to robotic-assisted radical nephrectomy. MUSIC found tumor size and complexity as key determinants, while the latter study pointed to patient-specific factors like age, BMI, and comorbidity index, rather than tumor characteristics, as significant predictors of surgical conversion. These insights emphasize the need for comprehensive pre-surgical assessments considering both tumor and patient health status [29, 30].

Together, these studies indicate that while tumor size and endophytic characteristics are important considerations, the overall demographic characteristics of the patient also play a significant role in surgical decision-making. This highlights the importance of comprehensive preoperative evaluation to predict surgical challenges and adjust approaches accordingly.

During the evaluation of perioperative characteristics between the conversion group and the no conversion group, a significant difference in EBL was noted. The median EBL for the conversion group was 91 mL, while for the control group, it was 77 mL, showing a statistically significant difference ($P=.039$). Additionally, the conversion group faced significant prolongation in surgery time due to difficulties in achieving hemostasis, with a median time of 125 min compared to 109 min for the control group ($P=.021$). This increase in duration is not only due to the time required to manage bleeding but also reflects the inherently time-consuming nature of traditional suturing techniques compared to the originally planned procedures. Literature indicates that intraoperative blood loss and extended surgery times are independent risk factors for postoperative complications. Despite employing effective hemostasis techniques, the conversion group continued to encounter challenges with ongoing bleeding and the limitations inherent in the techniques used. Similarly, prolonged surgeries increase oxygen debt, risk of organ failure, sepsis, and death, particularly in high-risk patients. Laparoscopic surgeries, involving carbon dioxide insufflation, can alter hemodynamics and stress hormones, posing risks, especially for the elderly or those with comorbidities [9]. Shorter operations, like SLPN, are crucial for minimizing surgical impact and enhancing recovery. Additionally, extended surgery durations strain resources and staff, potentially worsening patient outcomes, underscoring the need for refined surgical methods and intraoperative efficiency.

This study on SLPN offers crucial insights but has notable limitations, such as a small, institutionally-bound sample, potentially limiting broader applicability. Its retrospective design may introduce biases from incomplete or inconsistent records limits a full evaluation of SLPN's effectiveness. Additionally, variations in surgical techniques and surgeon expertise, which can significantly affect outcomes, were not thoroughly examined. Future research should focus on multicenter, diverse, and randomized controlled trials to enhance the reliability and generalizability of findings, alongside a detailed assessment of surgical methods and the refinement of surgeon skills to advance SLPN's safety and efficacy.

Conclusion

This study revealed that between 2016 and 2023, the conversion rate from SLPN to SPN was 5.9%, with LPN showing a higher conversion rate than RPN. Key factors influencing conversion included younger surgical age, higher preoperative eGFR, larger tumor size, and intrinsic tumor characteristics, underscoring the importance of individualized considerations in surgical planning and patient counseling. Furthermore, comprehensive preoperative assessment's role in anticipating surgical challenges and adjusting strategies was highlighted, offering valuable insights into enhancing the safety and efficacy of nephron-sparing surgeries.

Abbreviations

RCC	Renal Cell Carcinoma
PN	Partial Nephrectomy
WIT	Warm Ischemia Time
SLPN	Sutureless Partial Nephrectomy
SPN	Standard Partial Nephrectomy
ABC	Argon Beam Coagulator
LPN	Laparoscopic Partial Nephrectomy
RPN	Robotic-assisted Partial Nephrectomy
IQR	Interquartile Range
EGFR	Estimated Glomerular Filtration Rate
BMI	Body Mass Index
CCI	Charlson Comorbidity Index
ASA	American Society of Anesthesiologists
EBL	Stimated Blood Loss

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Author contributions

WL: project development, manuscript writing and editing. BH: manuscript writing and editing. SS: data analysis. WP: data collection. QY: manuscript writing and data analysis. BX: project development, manuscript writing.

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Data availability

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

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Shanghai Ninth People's Hospital (SH9H-2022-T359-1). All patients were given informed consent. All

experiments were performed in accordance with relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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