Endophytic Renal Cell Carcinoma Treated with Robot-Assisted Surgery: Functional Outcomes – A Comprehensive Review of the Current Literature

Keywords
Partial nephrectomy · Robotic surgical procedures · Endophytic mass · Intraparenchymal mass · Renal mass · Glomerular filtration rate

Abstract
**Introduction:** Robotic surgery for the management of localized renal cell carcinoma (RCC) has gained increasing popularity during the last decade. An endophytic renal tumour represents a surgical technical challenge in terms of identification and resection related to the lack of external visual cues on the kidney surface. **Materials and Methods:** There is little evidence of functional outcomes of robotic surgery on treating endophytic masses. For this reason, we wanted to review the contemporary literature on the functional outcomes of endophytic RCC treated with robotic surgery. **Results:** Many studies investigating robotic partial nephrectomy for totally endophytic RCC confirmed the good functional results of this approach at intermediate follow-up. The greater relative importance of volume loss versus ischaemia duration in predicting long-term renal function after partial nephrectomy is now established, and the robotic technique may facilitate volume preservation. Accurate use of intra-operative ultrasonography, enucleation, and intra-operative techniques using near-infrared fluorescence imaging with indocyanine green dye could minimize excision of the parenchyma and prevent devascularization of adjacent healthy parenchyma. **Conclusions:** Unfortunately, the overall quality of the literature evidence and the high risk of selection bias limit the possibility of any causal interpretation about the relationship between the surgical technique used and functional outcomes.

Introduction
Surgical management of a localized renal cell carcinoma (RCC) involves balancing cancer removal with an adequate margin, maximizing renal function, and avoiding peri-operative morbidity. Given the lack of cancer-specific survival benefit with radical nephrectomy over partial nephrectomy (PN) [1], the better renal function following nephron-sparing surgery, and the potential cardiovascular benefits with reduced risk of developing chronic kidney disease (CKD) [2, 3], current guidelines recommend prioritizing PN whenever technically feasible [4, 5].

Zine-Eddine Khene
Benoît Peyronnet
Anis Gasmi
Grégory Verhoest
Romain Mathieu
Karim Bensalah
Department of Urology, Rennes University Hospital, Rennes, France

© 2020 S. Karger AG, Basel
The introduction of robotic technology revolutionized minimally invasive surgery for RCC by overcoming many of the technical challenges of laparoscopy with a shorter learning curve [6]. The robotic platform facilitates precise and efficient execution of excision and renal reconstruction, which has led to its rapid dissemination. The increasing surgical experience in robotic PN (RPN) procedures worldwide gives the opportunity to perform operations in more complex and challenging renal cases [7–9].

Endophytic renal tumours represent a technical challenge due to the difficulties in tumour identification and resection related to the lack of external visual cues on the kidney surface. These difficulties may influence the perioperative outcomes of the procedure with longer warm ischaemia times (WITs), a higher rate of urinary system violation, and more frequent postoperative complications than those reported for standard and smaller tumours. Given its several potential inconveniences, the advantages of RPN for endophytic masses, notably regarding renal function, remain unclear.

This review aims to summarize and analyse the contemporary literature on the functional outcomes of endophytic RCC treated with robotic surgery.

Evidence Acquisition

A non-systematic MEDLINE/PubMed literature search was performed on March 2019 using the terms “Endophytic,” “Intraparenchymal,” “Renal mass,” “Robotic,” “Nephrectomy,” “Functional outcomes,” “Renal function,” and “Functional recovery.” Original articles were included based on their clinical relevance by two authors (Z.-E.K. and B.P.). Additional informative articles were collected by cross-referencing the bibliography of previously selected articles.

Determinants of Functional Outcomes after Partial Nephrectomy: Impact of Patient-, Imaging-, and Surgical-Related Factors

Quantity of Parenchyma Preserved

The proportion of parenchyma preserved seems to be a significant and independent determinant of functional outcome [10, 11]. Several authors have investigated potential methods for predicting the amount of preserved renal parenchyma. Examining pre-operative imaging parameters of a series of 98 PN s, Aertsen et al. [12] showed that loss of healthy renal parenchyma was highest in patients with renal sinus tumour involvement ($p = 0.003$), tumours with anterior location ($p = 0.006$), and high-grade postoperative complications ($p = 0.001$), but was not significantly correlated with medial/lateral location ($p = 0.940$) or exophytic/endophytic tumour growth ($p = 0.244$).

The RENAL (R – radius, E – exophytic vs. endophytic, N – nearness of tumour to collecting system, A – anterior vs. posterior, L – location relative to polar lines) nephrometry score [13] is a systematic approach designed to characterize renal masses and to develop a standardized reporting but not necessarily to guide clinical decisions [14]. Some teams have found that the RENAL nephrometry score correlates with renal volume loss and postoperative renal function, but groups have failed to identify a similar link [15].

The RENAL score was found to be associated with the pathologically determined non-neoplastic parenchymal volume removed ($\beta = 6.21, p < 0.001$) and the renal function decline in patients undergoing RPN. In a multivariate analysis of the RENAL components, the tumour radius ($\beta = 31.9, p < 0.001$) and tumour location relative to the polar lines of the kidney ($\beta = 5.26, p = 0.036$) were associated with greater non-neoplastic parenchymal volume removal [16].

Using renal scintigraphy in a cohort of 245 patients, Watts et al. [17] assessed the relationship between individual RENAL score constituents on renal function of the surgical kidney in patients undergoing laparoscopic or robotic PN. They found that the endophytic score of the tumour is associated with a significant decrease in split renal function of the surgical kidney at 1 year after surgery but not with overall renal function.

The concept of the surface area of tumour contact with the renal parenchyma (CSA) has also been studied as a predictor of functional outcomes after PN [18]. Early studies suggested strong performance characteristics of CSA can predict functional outcomes after PN [19, 20]. However, a more recent and comprehensive study suggested that the correlations between CSA and functional outcomes were only modest and that CSA was not an independent predictor for endophytic tumours [21].

Finally, Maurice et al. [22] retrospectively reviewed 880 partial nephrectomies to identify predictors of excisional volume loss (EVL) based on pathologic assessment. They observed that open PN (OPN) was associated with 7.8 cm$^3$ more EVL than RPN ($p < 0.01$). In comparison, for every 1-cm increase in tumour size, EVL increased by 7.1 cm$^3$ ($p < 0.01$), and for completely endophytic tumours, EVL increased by 7.8 cm$^3$ ($p = 0.01$).
Ischaemia Time

The subject of ischaemia time to impair renal function remains debatable. Several retrospective clinical studies published in the last decade have evaluated the effect of ischaemia time on postoperative renal function [23–25]. In a study based on a solitary kidney model, Thompson et al. [26] evaluated the effects of WIT and the quantity and quality of kidney preserved on renal functional recovery after PN. They showed that a WIT cut point of 25 min provided the best distinction between patients with and without postoperative acute renal failure and new-onset stage IV CKD (hazard ratio 2.27, 95% CI: 1.00–5.13; \( p = 0.049 \)). In a series of 32 patients, Funahashi et al. [27] quantified ischaemic renal damage using regional \(^{99m}\text{Tc-MAG3}\) uptake in the unaffected section of the surgically treated kidney. They found that a WIT of >25 min was associated with a long-term decrease in regional \(^{99m}\text{Tc-MAG3}\) uptake but that the surgically treated kidney recovered from the ischaemic insult when WIT was \( \leq \) 25 min. In a series of 99 patients, Zargar et al. [28] reported similar findings, but with a threshold of 30 min of ischaemia, whereas Choi et al. [29] drew comparable conclusions in 44 patients, but with a 28-min cut-off time.

In contrast to these studies and based on a host of biomarkers and multiple renal biopsies as surrogates for ischaemic injury, Parekh et al. [30] prospectively studied the tolerance of renal hilar clamping in humans. They found that renal functional changes did not correlate with ischaemia duration and that renal structural changes were much less severe than those observed in animal models that used similar durations of ischaemia. Recently published data by the same group of authors on long-term renal functional outcomes showed no correlation of ischaemia duration with renal function at 1-year follow-up [31]. In another study, Lane et al. [32] took into account the percentage of preserved parenchyma in a multivariate model that sought the predictors of a postoperative decrease in the estimated glomerular filtration rate (eGFR). They demonstrated in their multi-institutional cohort of 660 PNs of solitary kidneys that ischaemia time (warm or cold) was no longer a significant independent predictor of ultimate renal function.

Finally, the current evidence suggests that limited ischaemia time (i.e., \( \leq 25–30 \) min) has a lower risk of reducing renal function after PN. However, stronger evidence supports greater tolerance of the human renal parenchyma to limited ischaemia. The clinical relevance of these findings in different clinical settings will require further investigation.

Baseline Kidney Function

The quality of the renal parenchyma seems to be a critical determinant of functional recovery after nephron-sparing surgery. Consistent data indicate that the presence of baseline CKD is an important predictor of postoperative renal function after PN either in the single or bilateral kidney setting [26, 33]. Most recent studies indicate that pre-operative eGFR is an independent predictor of a significant decrease in eGFR in solitary kidneys and of the differential contribution of the operated organ in the presence of bilateral kidneys after adjusting for other patient-, tumour-, and surgery-related factors. Preoperative renal function may also have a dominant role over the number of residual nephrons in determining renal function because hyperfiltration of the remaining nephrons may compensate, to a certain degree, for their decreased number [34, 35].

Functional Outcomes of Partial Nephrectomy for Endophytic Tumours in the Literature

There are only a few published studies reporting the results of endophytic tumours resected with robotic surgery (Table 1).

In a series of 140 consecutive patients with completely endophytic tumours, Harke et al. [36] compared the outcomes of RPN and OPN. They showed that warm ischaemia was notably shorter for RPN with a WIT of 13 min compared to open surgery with 18 min, \( p = 0.001 \), and that there were comparable results for eGFR at discharge for both groups. Autorino et al. [37] reported their experience of RPN in completely intraparenchymal renal tumours. They included 65 patients who underwent RPN and compared the outcomes of endophytic masses with mesophytic and exophytic tumours and stated that they did not detect any differences in terms of surgical complications, positive margin rates, and postoperative changes in eGFR. However, the main limitations of this study included the short follow-up period (mean time was 12.6 months) and that the differences in eGFR were not standardized at established time points. Komminos et al. [38] performed a comparative analysis of 225 patients with renal tumours who underwent RPN, including 45 (40%) completely endophytic tumours, 19 (15.5%) exophytic tumours, and 47 (38%) mesophytic masses. The median follow-up times of the endophytic, mesophytic, and exophytic groups were 48, 43, and 38 months, respectively. They found a significantly higher rate of total artery clamped cases in the endophytic group (82.2%) com-
pared with the other groups (mesophytic, 72.4% and exophytic, 51.6%; \(p < 0.01\)). However, they did not find any significant differences among the groups regarding the latest postoperative eGFR and eGFR percentage change. Finally, they concluded that RPN for entirely intraparenchymal masses is a feasible procedure in terms of complication rates and functional and oncologic outcomes during an intermediate-term follow-up period.

In a cohort of 146 patients with completely endophytic renal tumours, Kara et al. [39] analysed the functional outcomes of RPN and OPN at a median follow-up of 15.2 months. The median percent eGFR preservation was 85.2% (76.4–93.3%), with no significant difference from OPN (\(p = 0.22\)). More recently, Abdel Raheem et al. [40] reported their experience with the robotic management of totally endophytic renal tumours with RPN. The authors compared the outcomes of endophytic masses managed by OPN or RPN and stated that they did not detect any differences in terms of surgical complications, positive margin rates, and postoperative changes in eGFR. They showed that the median percent eGFR preservation in the RPN group was 88% (80–100%) at a median follow-up of 59 months. The main strengths of this study are the relative long-term functional outcomes and the demonstration of the feasibility, long-term oncologic safety, and renal function preservation of robotic surgery as an effective alternative to open surgery in the treatment of such difficult lesions.

### Review of Functional Outcomes of Partial Nephrectomy for Endophytic Tumours

As pre-operative renal function is a non-modifiable factor and there is low-grade evidence to support that limited ischaemia time (i.e., \(\leq 25\) min) has a lower risk of reducing renal function after PN, the amount of healthy parenchyma preserved appears to be the main potentially modifiable predictor of ultimate renal function.

### Improving and Minimizing Excision of Parenchyma

Several intra-operative techniques were developed to help surgeons during RPN, including tumour delineation, tumour differentiation from normal kidney parenchyma, and kidney perfusion during clamping.

Intra-operative ultrasonography is widely used as a real-time intra-operative imaging technique during RPN, especially in cases of totally endophytic tumours. It is used by the assistant during the procedure, and images are projected onto the console screen. Using intra-operative ultrasonography allows the identification of the location, margin, and depth of the endophytic renal tumour before surgery. In addition, the direct contact of the transducer on the kidney capsular surface helps in reducing artefacts and visualization difficulties, detecting additional small renal masses, and characterizing the anatomic relationship of the renal mass to adjacent structures such as the

| Reference                  | Study period | Study design | Study origin | Patients, \(n\) | Surgical technique | Tumour size, cm | RENAL score | WIT, min | Follow-up, months | Functional outcomes | LE |
|----------------------------|--------------|--------------|--------------|----------------|-------------------|----------------|-------------|---------|------------------|---------------------|----|
| Raheem et al. [40], 2019   | 2005–2015    | Retrospective| Korea        | 89             | 52 RPN            | 2.8            | 8.9         | 24      | 59               | CKD upstaging occurs in (5.4%) | 3  |
|                            |              |              |              | 37 OPN         |                   | 2.5            | 8.3         | 27      | 53               |                      |    |
| Harke et al. [36], 2018    | 2008–2016    | Retrospective| Germany      | 140            | 64 RPN            | 2.5            | 11          | 13      | –                | Latest median% eGFR preservation 72.5 | 3  |
|                            |              |              |              | 76 OPN         |                   | 2.6            | 11          | 18      | –                | Latest median% eGFR preservation 68.2 |    |
| Kara et al. [39], 2016     | 2011–2016    | Retrospective| USA          | 143            | 87 RPN            | 2.8            | 9           | 17.5    | 15.2             | Latest median% eGFR preservation 85.2 | 3  |
|                            |              |              |              | 56 OPN         |                   | 3.1            | 9           | 20.6    | 18.1             | Latest median% eGFR preservation 82.9 |    |
| Komninos et al. [38], 2014 | 2006–2013    | Retrospective| Korea        | 45             | RPN               | 2.6            | 9           | 24      | 48               | Latest median% eGFR change –4.5 | 3  |
| Autorino et al. [37], 2014 | 2006–2012    | Retrospective| USA          | 65             | RPN               | 2.6            | 8.7         | 21.7    | 12.6             | Latest mean% eGFR change –9.4 | 3  |

eGFR, estimated glomerular filtration rate; CKD, chronic kidney disease; WIT, warm ischemia time; RPN, robot-assisted partial nephrectomy; OPN, open partial nephrectomy; LE, level of evidence.

---

Table 1. Literature data of endophytic renal tumour outcomes following partial nephrectomy surgery

---

 Ways to Optimize the Functional Outcomes of Partial Nephrectomy for Endophytic Tumours

As pre-operative renal function is a non-modifiable factor and there is low-grade evidence to support that limited ischaemia time (i.e., \(\leq 25\) min) has a lower risk of reducing renal function after PN, the amount of healthy parenchyma preserved appears to be the main potentially modifiable predictor of ultimate renal function.
pelvicalyceal system, renal sinus, and major blood vessels to determine the best surgical resection site [41–43].

Initially described as an imperative indication, simple tumour enucleation has been proposed as a technique that can maximize the preservation of parenchyma during PN [44–46].

Enucleation is an alternative nephron-sparing technique in which the renal mass is dissected away from the normal parenchyma via an avascular plane along the fibrous tumour pseudocapsule [47]. It is a well-described surgical technique for familial RCC that is increasingly applied to sporadic cases, potentially offering improved volume preservation while obviating the need for formal capsular renorrhaphy.

Enucleation has been used in RPN; however, widespread adoption has been curtailed by concerns about the oncological efficacy. Studies have suggested that tumour enucleation has the potential for maximum parenchymal preservation and optimized functional recovery [45]. A recent meta-analysis showed that tumour enucleation is non-inferior to standard PN regarding positive margin rate and tumour recurrence rates [48]. An alternative to enucleation could be to minimize the rim of the excised adjacent normal parenchyma and to limit devascularization of the adjacent parenchyma during renal reconstruction by optimizing renorrhaphy.

Similar to enucleation, the anatomic “minimal-margin” RPN technique decreases parenchymal loss by leaving minimal parenchymal tissue on the tumour, achieving greater renal parenchymal preservation; however, its oncological safety compared with that of the traditional RPN technique remains to be seen.

Minimizing Ischaemia

A relatively new development in RCC surgery is intraoperative fluorescence imaging. The most commonly used near-infrared fluorescent (NIRF) dye is indocyanine green (ICG). It is used to differentiate the tumour from normal kidney parenchyma and to confirm adequate ischaemia during selective clamping of renal artery branches. Consequently, it could reduce the proportion of renal parenchyma that is subjected to ischaemia and excision. In the field of robotic surgery, several studies have employed NIR imaging to aid in selective arterial clamping and to limit the proportion of healthy parenchyma during RPN. In 2012, Krane et al. [49] performed the first prospective study comparing 47 patients who underwent RPN with the application of ICG to 47 patients treated previously without. They found that WIT was significantly decreased in the ICG group (15 vs. 17 min, \(p = 0.01\)). However, there was no significant difference between the groups for percent change in GFR at discharge (–4.6 vs. –7.4%, \(p = 0.5\)). In another matched-pair analysis, McClintock et al. [50]. found that selective clamping with NIRF was associated with superior kidney function at discharge, as demonstrated by postoperative eGFR (78.2 vs. 68.5 mL/min per 1.73 m\(^2\); \(p = 0.04\)), absolute reduction of eGFR (–2.5 vs. –14.0 mL/min per 1.73 m\(^2\); \(p < 0.01\)), and percent change in eGFR (–1.9 vs. –16.8%, \(p < 0.01\)). However, the differences did not reach conventional statistical significance (–3.1 vs. –14.6%, \(p = 0.07\))

Preventing Devascularization of Adjacent Healthy Parenchyma

Initially described as an imperative indication, simple tumour enucleation has been proposed as a technique that can maximize the preservation of parenchyma during PN [44–46].

Enucleation is an alternative nephron-sparing technique in which the renal mass is dissected away from the normal parenchyma via an avascular plane along the fibrous tumour pseudocapsule [47]. It is a well-described surgical technique for familial RCC that is increasingly applied to sporadic cases, potentially offering improved volume preservation while obviating the need for formal capsular renorrhaphy.

Enucleation has been used in RPN; however, widespread adoption has been curtailed by concerns about oncological efficacy. Studies have suggested that tumour enucleation has the potential for maximum parenchymal preservation and optimized functional recovery [45]. A recent meta-analysis showed that tumour enucleation is non-inferior to standard PN regarding positive margin rate and tumour recurrence rates [48]. An alternative to enucleation could be to minimize the rim of the excised adjacent normal parenchyma and to limit devascularization of the adjacent parenchyma during renal reconstruction by optimizing renorrhaphy.

Similar to enucleation, the anatomic “minimal-margin” RPN technique decreases parenchymal loss by leav-
ing minimal parenchymal tissue on the tumour, achieving greater renal parenchymal preservation; however, its oncological safety compared with that of the traditional RPN technique remains to be seen.

Improving parenchymal volume preservation through omission or modification of renorrhaphy techniques is still under investigation [52]. During RPN, renorrhaphy typically included a double-layer technique [53]. In a small series of 15 RPN cases performed with a deep suture layer but without cortical renorrhaphy matched 2:1 with traditional two-layered RPN cases, Bahler et al. [54] observed that the non-renorrhaphy group was associated with shorter WITs and decreased parenchymal volume loss (9 vs. 17 cm³, p < 0.01) with a trend toward improved GFR preservation. Renorrhaphy techniques using tissue-adhesive sealant have also been described and seem to represent viable alternatives for renorrhaphy that may offer potential decreases in volume loss and consequent improvements in renal function but without a significantly increased risk of complications [55].

Limitations and Perspective

Robotic surgery for completely endophytic RCC presents many surgical challenges: (1) these tumours are not easily identifiable on visual inspection, and (2) the depth of resection is not immediately apparent, which increases the technical difficulty of the surgery and the risk of complications. Regardless of this increased technical complexity, the goals of the surgery remain the same: to achieve oncological control, to avoid complications, and to maximally preserve renal function. The current literature reported that RPN can be effectively and safely performed for endophytic localized tumours in terms of excellent perioperative outcomes, including renal function and oncological safety. The accurate use of intra-operative ultrasonography and intra-operative techniques using NIRF imaging with ICG dye could facilitate this surgery. However, in terms of comparing functional outcomes, it is difficult to draw strong conclusions based on the data reported due to inherent differences in ischaemia type, resection technique, and the percentage of volume preservation. Moreover, most of these studies are based on two-kidney models and serum creatinine-based assessments of renal function that evaluate global renal function in patients with a contralateral kidney.

In conclusion, robotic surgery is a feasible, safe, and oncologically effective surgical treatment for endophytic RCC. However, the current literature does not provide a major advantage for RPN when compared to standard laparoscopy or open surgery in terms of preserving renal function. Additional studies of high-level evidence are required to confirm these findings.

Disclosure Statement

The authors declare that they have no conflicts of interest to disclose.

Funding Sources

The authors have no funding sources to disclose.

Author Contributions

Z.-E.K., B.P., and A.G: conception or design of the work; acquisition, analysis, or interpretation of data; and drafting or revising the work. K.B. and R.M: conception or design of the work; drafting or revising the work; and interpretation of data.

References

1 Van Poppel H, Da Pozzo L, Albrecht W, Mateev V, Bono A, Borkowski A, et al. A prospective, randomised EORTC intergroup phase 3 study comparing the oncologic outcome of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol. 2011 Apr;59(4):543–52.
2 Kaushik D, Kim SP, Childs MA, Lohse CM, Costello BA, Cheville JC, et al. Overall survival and development of stage IV chronic kidney disease in patients undergoing partial and radical nephrectomy for benign renal tumors. Eur Urol. 2013 Oct;64(4):600–6.
3 Kim SP, Thompson RH, Boorjian SA, Weight CJ, Han LC, Murad MH, et al. Comparative effectiveness for survival and renal function of partial and radical nephrectomy for localized renal tumors: a systematic review and meta-analysis. J Urol. 2012 Jul;188(1):51–7.
4 Campbell S, Uzzo RG, Afla ME, Bass EB, Cadeddu JA, Chang A, et al. Renal Mass and Localization Renal Cancer: AUA Guideline. J Urol. 2017 Sep;198(3):520–9.
5 Ljungberg B, Bensalah K, Canfield S, Dabestani S, Hofmann F, Hora M, et al. EAU guidelines on renal cell carcinoma: 2014 update. Eur Urol. 2015 May;67(5):913–24.
6 Faria EF, Caputo PA, Wood CG, Karam JA, Nogueras-González GM, Matin SF. Robotic partial nephrectomy shortens warm ischemia time, reducing suturing time kinetics even for an experienced laparoscopic surgeon: a comparative analysis. World J Urol. 2014 Feb;32(1):265–71.
7 Ubrig B, Roosen A, Wagner C, Trabs G, Schiefelbein F, Witt JH, et al. Tumor complexity and the impact on MIC and trifecta in robot-assisted partial nephrectomy: a multicenter study of over 500 cases. World J Urol. 2018 May;36(5):783–8.
Robot-Assisted Surgery for Endophytic Renal Tumours

Abdel Raheem A, Alatawi A, Soto I, Kim DK, Kim LH, Santok GD, et al. Robot-assisted partial nephrectomy confers excellent long-term outcomes for the treatment of complex cystic renal tumors: median follow up of 58 months. Int J Urol. 2016 Dec;23(12):976–82.

Hennessy DB, Wei G, Moon D, Kinnee N, Bolton DM, Lawrentschuk N, et al. Strategies for success: a multi-institutional study on robot-assisted partial nephrectomy for complex renal lesions. BJU Int. 2018 May;121 Suppl 3: 40–5; Jan 29(1):29–34.

Marconi L, Desai MM, Ficarra V, Porpiglia F, Van Poppel H. Renal Preservation and Partial Nephrectomy: Patient and Surgical Factors. Eur Urol Focus. 2016 Dec;2(6):589–600.

Mir MC, Campbell RA, Sharma N, Remer EM, Simmons MN, Li J, et al. Parenchymal volume preservation and ischemia during partial nephrectomy: functional and volumetric analysis. Urology. 2013 Aug;Aug(2):263–8.

Aertsen M, De Keyzer F, Van Poppel H, Joniau S, De Wever L, Lerut E, et al. Tumour-related imaging parameters predicting the percentage of preserved normal renal parenchyma following nephron sparing surgery: a retrospective study. Eur Radiol. 2013 Jan;23(1):280–6.

Kutikov A, Uzzo RG. The R.E.N.A.L. nephrometry score: a comprehensive standardized system for quantitating renal tumor size, location and depth. J Urol. 2009 Sep;182(3):844–53.

Khene ZE, Peyronnet B, Ferlon L, Graffiele V, Pradere B, Robert C, et al. What is better for predicting morbidity of robotic partial nephrectomy – a score or your clinical judgement? Eur Urol Focus. 2020 Mar;6(2):313–9.

Tanaka K, Furukawa J, Shigemura K, Hinata N, Ishimura T, Muramaki M, et al. Surgery-related outcomes and postoperative split renal function by scintigraphy evaluation in robot-assisted partial nephrectomy in complex renal tumors: an initial case series. J Endourol. 2015 May;29(5):552–7.

Husain EZ, Rosen DC, Paulucci DJ, Sfakianos JP, Abaza R, Badani KK. R.E.N.A.L. Nephrometry Score Predicts Non-neoplastic Parenchymal Volume Removed During Robotic Partial Nephrectomy. J Endourol. 2016 Oct;30(10):1099–104.

Watts KL, Ghosh P, Stein S, Ghavamian R. Value of nephrometry score constituents on perioperative outcomes and split renal function in patients undergoing minimally invasive partial nephrectomy. Urology. 2017 Jan;99:112–7.

Leslie S, Gill IS, de Castro Abreu AL, Rahmanuddin S, Gill KS, Nguyen M, et al. Renal tumor contact surface area: a novel parameter for predicting complexity and outcomes of partial nephrectomy. Eur Urol. 2014 Nov;66(5):884–93.

Hsieh PF, Wang YD, Huang CP, Wu HC, Yang CR, Chen GH, et al. A Mathematical Method to Calculate Tumor Contact Surface Area: An Effective Parameter to Predict Renal Function after Partial Nephrectomy. J Urol. 2016 Jul;196(1):33–40.

Hailer M, Ristau BT, Higgins AM, Smaldone MC, Kutikov A, Zisman A, et al. External Validation of Contact Surface Area as a Predictor of Postoperative Renal Function in Patients Undergoing Partial Nephrectomy. J Urol. 2018 Mar;199(3):649–54.

Suk-Ouichai C, Wu J, Dong W, Tanaka H, Wang Y, Zhang JI, et al. Tumor contact surface area as a predictor of functional outcomes after standard partial nephrectomy: utility and limitations. Urology. 2018 Jun;116:106–13.

Maurice MJ, Ramirez D, Malik A, Kara Ö, Nelson RJ, Caputo PA, et al. Predictors of Excisional Volume Loss in Partial Nephrectomy: Is There Still Room for Improvement? Eur Urol. 2016 Sep;70(3):413–5.

Volpe A, Blute ML, Ficarra V, Gill IS, Kutikov A, Porpiglia F, et al. Renal Ischemia and Function After Partial Nephrectomy: A Collaborative Review of the Literature. Eur Urol. 2015 Jul;68(1):61–74.

Rod X, Peyronnet B, Seisen T, Pradere B, Gozzer FD, Verhoest G, et al. Impact of ischemia time on renal function after partial nephrectomy: a systematic review. BJU Int. 2016 Nov;118(5):692–705.

Mir MC, Pavan N, Parekh DJ. Current Paradigm for Ischemia in Kidney Surgery. J Urol. 2016 Jun;195(6):1655–63.

Thompson RH, Lane BR, Lohe CM, Leibovitch BC, Fergany A, Frank L, et al. Renal function after partial nephrectomy: effect of warm ischemia relative to quantity and quality of preserved kidney. Urology. 2012 Feb;79(2):356–60.

Funahashi Y, Hattori R, Yamamoto T, Sassa N, Fujita T, Gotoh M. Effect of warm ischemia on renal function during partial nephrectomy: assessment with new 99mTc-mercapto- acetyltriglycine scintigraphy parameter. Urology. 2012 Jan;79(1):160–4.

Zargar H, Akca O, Auturino R, Brandao LF, Laydner H, Krishnan J, et al. Ipsilateral renal function preservation after robot-assisted partial nephrectomy (RPN): an objective analysis using mercapto-acetyltriglycine (MAG3) renal scan data and volumetric assessment. BJU Int. 2015 May;115(5):787–95.

Choi JD, Park JW, Choi JY, Kim HS, Jeong BC, Jeon SS, et al. Renal damage caused by warm ischaemia during laparoscopic and robot-assisted partial nephrectomy: an assessment using Tc 99m-DTPA glomerular filtration rate. Eur Urol. 2010 Dec;58(6):900–5.

Parekh DJ, Weinberg JM, Ercole B, Torkko MC, Kutikov A, et al. Tolerance of the human kidney to isolated controlled ischemia. J Am Soc Nephrol. 2013 Feb;24(3):506–17.

Kallingal GJ, Weinberg JM, Reis IM, Nehra A, Venkatachalam MA, Parekh DJ. Long-term response to renal ischaemia in the human kidney after partial nephrectomy: results from a prospective clinical trial. BJU Int. 2016 May;117(5):766–74.

Lane BR, Russo P, Uzzo RG, Hernandez AV, Boorjian SA, Thompson RH, et al. Comparison of cold and warm ischemia during partial nephrectomy in 660 solitary kidneys reveals predominant role of nonmodifiable factors in determining renal function. J Urol. 2011 Feb;185(2):421–7.

Desai MM, Gill IS, Ramani AP, Spalviero M, Rychicki L, Kaouk JH. The impact of warm ischaemia on renal function after laparoscopic partial nephrectomy. BJU Int. 2005 Feb;95(3):377–83.

Antonelli A, Mari A, Longo N, Novara G, Porpiglia F, Schiavina R, et al.; Collaborators. Role of Clinical and Surgical Factors for the Prediction of Immediate, Early and Late Functional Results, and its Relationship with Cardiovascular Outcome after Partial Nephrectomy: Results from the Prospective Multicenter RECORD1 Project. J Urol. 2018 Apr;199(4):927–32.

Winer AG, Zabor EC, Vacchio MJ, Hakimi AA, Russo P, Coleman JA, et al. The Effect of Patient and Surgical Characteristics on Renal Function After Partial Nephrectomy. Clin Genitourin Cancer. 2018 Jun;16(3):191–6.

Harke NN, Mandel P, Witt JH, Wagner C, Panic A, Boy A, et al. Are there limits of robotic partial nephrectomy? TRIFECTA outcomes of open and robotic partial nephrectomy for completely endophytic renal tumors. J Surg Oncol. 2018 Jul;118(1):206–11.

Autorino R, Khalifeh A, Laydner H, Samaraksera D, Rizkala E, Eyraud R, et al. Robot-assisted partial nephrectomy (RPN) for completely endophytic renal masses: a single institution experience. BJU Int. 2014 May;113(5):762–8.

Komminos C, Shin TY, Tuliao P, Kim DK, Han WK, Chung BH, et al. Robotic partial nephrectomy for completely endophytic renal tumors: complications and functional and oncologic outcomes during a 4-year median period of follow-up. Urology. 2014 Dec;84(6):1367–73.

Kara O, Maurice MJ, Malik A, Ramirez D, Nelson RJ, Caputo PA, et al. Comparison of robot-assisted and open partial nephrectomy for completely endophytic renal tumors: a single center experience. BJU Int. 2016 Dec;118(6):946–51.

Abdel Raheem A, Chang KD, Alzeni MJ, Lum TG, Ham WS, Han WK, et al. Robot-Assisted Partial Nephrectomy for Totally Endophytic Renal Tumors: Step by Step Standardized Surgical Technique and Long-Term Outcomes with a Median 59-Month Follow-Up. J Laparoendosc Adv Surg Tech A. 2019 Jan;29(1):1–11.
41 Polascik TJ, Meng MV, Epstein JI, Marshall FF. Intraoperative sonography for the evaluation and management of renal tumors: experience with 100 patients. J Urol. 1995 Nov;154(5):1676–80.

42 Kaczmarek BF, Sukumar S, Petros F, Trinh QD, Mander N, Chen R, et al. Robotic ultrasound for tumor identification in robotic partial nephrectomy: initial series and outcomes. Int J Urol. 2013 Feb;20(2):172–6.

43 Di Cosmo G, Verzotti E, Silvestri T, Lissiani A, Knez R, Pavan N, et al. Intraoperative ultrasound in robot-assisted partial nephrectomy: state of the art. Arch Ital Urol Androl. 2018 Sep;90(3):195–8.

44 Minervini A, Ficarra V, Rocco F, Antonelli A, Bertini R, Carmignani G, et al.; SATURN Project-LUNA Foundation. Simple enucleation is equivalent to traditional partial nephrectomy for renal cell carcinoma: results of a nonrandomized, retrospective, comparative study. J Urol. 2011 May;185(5):1604–10.

45 Dong W, Gupta GN, Blackwell RH, Wu J, Suk-Ouihai C, Shah A, et al. Functional Comparison of Renal Tumor Enucleation Versus Standard Partial Nephrectomy. Eur Urol Focus. 2017 Oct;3(4-5):437–43.

46 Blackwell RH, Li B, Kozel Z, Zhang Z, Zhao J, Dong W, et al. Functional implications of renal tumor enucleation relative to standard partial nephrectomy. Urology. 2017 Jan;99:162–8

47 Gupta GN, Boris RS, Campbell SC, Zhang Z. Tumor Enucleation for Sporadic Localized Kidney Cancer: pro and Con. J Urol. 2015 Sep;194(3):623–5.

48 Minervini A, Campi R, Sessa F, Derweesh I, Kaouk JH, Mari A, et al. Positive surgical margins and local recurrence after simple enucleation and standard partial nephrectomy for malignant renal tumors: systematic review of the literature and meta-analysis of prevalence. Minerva Urol Nefrol. 2017 Dec;69(6):523–38.

49 Krane LS, Manny TB, Hemal AK. Is near infrared fluorescence imaging using indocyanine green dye useful in robotic partial nephrectomy? A prospective comparative study of 94 patients. Urology. 2012 Jul;80(1):110–6.

50 McClintock TR, Bjurlin MA, Wysock JS, Borofsky MS, Marien TP, Okoro C, et al. Can selective arterial clamping with fluorescence imaging preserve kidney function during robotic partial nephrectomy? Urology. 2014 Aug;84(2):327–32.

51 Simone G, Tuderti G, Anceschi U, Ferriero M, Costantini M, Minisola F, et al. “Ride the Green Light”: indocyanine green-marked off-clamp robotic partial nephrectomy for totally endophytic renal masses. Eur Urol. 2019 Jun;75(6):1008–14.

52 Bertolo R, Campi R, Klatte T, Kriegmair MC, Mir MC, Ouzaid I, et al. Suture techniques during laparoscopic and robot-assisted partial nephrectomy: a systematic review and quantitative synthesis of peri-operative outcomes. BJU Int. 2019 Jun;123(6):923–46.

53 Kaouk JH, Khalifeh A, Hillyer S, Haber GP, Stein RJ, Autorino R. Robot-assisted laparoscopic partial nephrectomy: step-by-step contemporary technique and surgical outcomes at a single high-volume institution. Eur Urol. 2012 Sep;62(3):553–61.

54 Bahler CD, Dube HT, Flynn KJ, Garg S, Monn MF, Gutwein LG, et al. Feasibility of omitting cortical renorrhaphy during robot-assisted partial nephrectomy: a matched analysis. J Endourol. 2013 May;27(5):548–55.

55 Takagi T, Kondo T, Omae K, Iizuka J, Kobayashi H, Yoshida K, et al. Assessment of Surgical Outcomes of the Non-renorrhaphy Technique in Open Partial Nephrectomy for ≥T1b Renal Tumors. Urology. 2015 Sep;86(3):529–33.