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REVIEW

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Surgical approach and atypical recurrence after radical nephrectomy: considerations for cytoreductive nephrectomy in the metastatic setting

Rachel C. Bernardo[a], Michael Wynne[a], Michelle Wang[a], Diego Gonzalez[a], Sam Kwon[a], Fiona Wardrop[a], Michael Whalen[b,*]

[a] *The George Washington University School of Medicine and Health Sciences, Washington, DC, USA.*
[b] *The George Washington University Medical Faculty Associates, Department of Urology, Washington, DC, USA.*

Abstract

Radical nephrectomy (RN) remains an important therapeutic option in the management of renal cell carcinoma (RCC), including in the metastatic setting where cytoreductive nephrectomy (CN) may be pursued in select patients with good performance status and limited disease burden. While typical patterns of recurrence after CN are well established, atypical intraperitoneal recurrences (ATR) have emerged as rare but clinically relevant events in the era of improved systemic therapies and prolonged survival. In this structured literature review, we identified and analyzed 80 studies describing ATR after RN (localized or metastatic). Across reports, most ATR followed minimally invasive approaches (laparoscopic or robotic). In the largest cohort focused on ATR (n~58), index procedures were laparoscopic in ~55% and robotic in ~45%; recurrence most often involved the nephrectomy bed/perinephric implants (~48% alone; ~29% with other intra-abdominal sites), with port-site disease in ~22% (~5% isolated) and isolated intraperitoneal metastases in ~12%. ATR typically occurred within 18 months (~62%), and 5-year survival from ATR was ~58%, with notably favorable outcomes for low-grade primaries. Risk factors for ATR include high tumor grade, sarcomatoid differentiation, tumor necrosis, and potential surgical factors such as tumor spillage, specimen morcellation, and improper use of retrieval bags. Although technical breaches were implicated in several cases, ATR may also arise independent of these factors, likely reflecting the complex interplay between tumor biology, surgical approach, and host factors. The current evidence is limited by retrospective design, publication bias, and lack of standardization in reporting. Our findings underscore the need for future multicenter prospective studies with consistent definitions and long-term surveillance to better characterize ATR incidence and outcomes. Additionally, technical refinements such as strict adherence to oncologic principles, containment during specimen extraction, and avoidance of morcellation in high-risk cases may mitigate risk. As CN becomes more widely employed alongside modern systemic therapies, understanding and mitigating the risk of ATR will be critical in optimizing surgical decision-making in the metastatic RCC population.

Keywords: Renal cell carcinoma, cytoreductive nephrectomy, atypical recurrence, port-site metastasis, minimally invasive surgery

Introduction

Radical nephrectomy (RN) has historically been a cornerstone of treatment for renal cell carcinoma (RCC) across both localized and metastatic disease settings. In patients with metastatic RCC (mRCC), cytoreductive nephrectomy (CN) remains part of the management algorithm for select patients with limited metastatic disease and good performance status (*i.e.* International Metastatic Renal Cell Carcinoma Disease Consortium [IMDC] low risk) [1-3]. As systemic therapies have improved and overall survival has increased, atypical intraperitoneal recurrence (ATR), such as peritoneal carcinomatosis or port-site metastases, is being recognized [4, 5]. ATR is rare but clinically relevant, and its pathogenesis remains poorly understood. The

* Corresponding author: Michael Whalen
Mailing address: 2150 Pennsylvania Avenue, Washington, DC 20037, USA.
Email: mwhalen@gwmail.gwu.edu
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emergence of ATR may reflect not only improvements in imaging and surveillance but also possible surgical factors and tumor biology, particularly in the context of minimally invasive approaches [6]. Although most published cases describe ATR following nephrectomy for localized RCC, the growing use of CN in the metastatic setting necessitates a closer examination of recurrence patterns in this high-risk population. This review synthesizes available data on ATR following RN, highlights technical and tumor-related risk factors, and explores implications for surgical practice, particularly in patients undergoing CN for metastatic disease.

Methods

We conducted a structured literature search of the National Library of Medicine database (PubMed) from January 1962 to February 2025 using search terms related to renal cell carcinoma, nephrectomy, cytoreductive nephrectomy, peritoneal carcinomatosis, port-site metastasis, and atypical recurrence. Appropriate MeSH terms and appropriate nesting and Boolean operators were used to modify the search. We analyzed and reviewed 80 studies. Eligible studies included all reports of atypical intraperitoneal or port-site recurrence following RN, in either the localized or metastatic setting. Reviews, meta-analyses, and case reports/series were also included. Editorials, commentaries and letters to the editor were excluded. Data extracted included surgical approach, recurrence pattern, tumor characteristics, histology, and patient outcomes.

Results

Surgical approaches

RN involves the surgical removal of the kidney, often with surrounding structures such as perirenal fat, regional lymph nodes, and the ipsilateral adrenal gland. According to the American Urological Association 2021 guidelines, clinicians should consider a RN for "patients with a solid or Bosniak 3-4 complex cystic renal mass with increased oncologic potential suggested by tumor size, renal mass biopsy, and/or imaging." This procedure can be performed by an open incision or with a minimally invasive approach (laparoscopic or robotic). These techniques differ in terms of invasiveness, recovery time, surgical complexity, and clinical outcomes. According to the GRAND study [7], which analyzed data from nearly 194,000 patients in Germany who underwent RN between 2005 and 2021, 83% of procedures were performed using open technique, 15% were laparoscopic, and 2.2% were robotic. Notably, this study highlighted a steady decline in the use of open approaches since 2005.

In open RN, a large abdominal or flank incision of approximately 10-20 cm allows the surgeon direct access to the kidney. In laparoscopic RN, the surgeon makes several incisions in the abdomen to insert a camera and specialized instruments. Robotic-assisted RN builds upon the laparoscopic approach, using a robotic system to enhance precision and dexterity, particularly in complex cases. In a retrospective population-based cohort study from 2004 to 2013, minimally invasive surgery was not associated with differences in overall survival or disease specific survival compared to open surgical resection [8]. In addition, the total hospital cost has been noted to be higher when the robotic-assisted approach is applied compared to open [9]. However, studies have demonstrated both perioperative recovery and cosmetic advantages to minimally invasive RN compared to open-surgery in well-selected patients [10].

Patients with high tumor burden, extensive local inflammation, or peritoneal adhesions may present with technical challenges, particularly for minimally invasive procedures. These conditions can obscure anatomical planes, increase operative time, and elevate the risk of complications. The use of pneumoperitoneum (insufflation of the abdomen with CO_2) during minimally invasive procedures has been hypothesized to promote tumor dissemination, although clinical evidence is limited. There is also concern regarding port-site metastasis, especially in the context of advanced or poorly contained tumors. Furthermore, tumor handling during laparoscopic or robotic extraction must be meticulous to prevent capsule rupture or tumor spillage. These risks highlight the importance of careful patient selection and surgical technique in RN.

Defining atypical intraperitoneal recurrence

RCC most commonly metastasizes to the lungs, liver, bone, brain or lymph nodes, typically via hematogenous or lymphatic routes. Following RN in the localized setting, recurrences are mostly commonly found at these sites, or locally within the renal fossa itself, especially in the setting of positive surgical margin. Nearly half of all recurrences occur within two years of surgical intervention [11]. ATR following nephrectomy can be defined as any recurrence of disease in an unusual anatomic location or within an unexpected timeline relevant to typical metastatic pattern of RCC. Sites of ATR that have been described in literature to date include but are not limited to thyroid, bladder, skeletal muscle, skin, peritoneal implants, port sites, and various gastrointestinal organs [12-17]. The mechanism by which ATR occurs has been debated. It is ultimately likely multifactorial and varies between patients. Proposed mechanisms include: accidental deposition of cancerous cells directly into surgical wounds especially during specimen extraction, aerosolization of tumor cells within the peritoneal cavity during insufflation or desufflation, immunomodulation from pneumoperitoneum, escape of tumor cells in lymphatic or vascular pathways in a pressurized abdomen, and spread via instruments that have violated tumor margins [6, 18-20]. The etiology of ATR is also likely heavily influenced by tumor biology, histopathologic factors, and local wound factors [21, 22]. The exact incidence of ATR is unknown, however in the largest available case series on ATR following partial or RN we see that ATR is often associated

with poor prognosis even with extensive multidisciplinary treatment strategies [18].

Incidence and patterns

ATRs have a generally undefined incidence, estimated to range from 0.9% to 4% [21]. In the largest cohort to date, Russo *et al.* examined 58 patients who underwent nephrectomy for localized disease and subsequently developed ATR: 32 (55%) patients underwent laparoscopic surgery, while 26 (45%) underwent robotic surgery for their primary tumor. Clear cell carcinoma was the most common histology (67%), followed by sarcomatoid (17%) and rhabdoid (6.9%). In this patient cohort who developed ATR, most had localized disease at the time of nephrectomy: 29 (50%) had pT1 tumors, 6 (10%) had pT2, and 21 (36%) had locally advanced pT3 tumors. A total of 36 (62%) patients had recurrence within 18 months, 16 (28%) between 18 and 60 months, and six (10%) at > 60 months. Tumor recurrence was incidentally identified in 83% of cases (*i.e.* asymptomatic on imaging), with 57% occurring at distant sites. The nephrectomy bed or perinephric tumor implants were affected either alone in 48% of patients or alongside intraperitoneal and port-site metastases in 29%. Port-site metastases were observed in 22% of cases, appearing in isolation in 5% and with other metastatic sites in 17%. In 12% of patients, intraperitoneal metastases represented the only site of abdominal tumor recurrence. Unfortunately, this recurrence information was not specified between the robotic and laparoscopic cases. There was no significant difference in the time to recurrence between patients with clear cell RCC (ccRCC) (median 8 months, IQR 5–21) and those with non–ccRCC. At a median follow-up of 59 months, 21 patients (36%) had died (median time to death: 36 months), 28 (48%) were alive, and 9 (16%) had no evidence of disease. The overall 5-year survival from the time of ATR to last follow-up or death was 58.4% (95% CI: 45.2–75.5%) at a median follow-up of 41 months. Notably, all patients with low-grade tumors were alive at last follow-up despite experiencing ATR [18].
There are also a handful of case reports describing laparoscopic surgeries with atypical intraperitoneal recurrences. Most commonly, these come in the form of port site metastases. However, there are other descriptions of recurrence as peritoneal masses, intrahepatic, renal fossa, or bony pelvis [17, 23-26]. Only one case report describing atypical peritoneal recurrence in an open surgical approach exists at this time, with Ohtaki *et al.* describing the growth of an abdominal wall desmoid tumor beneath the incision site after removal of ccRCC. Two robotic cases outside of Russo *et al.*'s larger study have been reported. In Song *et al.*'s study, a 68-year-old man developed a port-site metastasis five months after undergoing robot-assisted partial nephrectomy (PN) for a 4 cm right renal mass (stage T1aN0M0). The isolated peritoneal recurrence at the camera-port site was confirmed to be RCC upon biopsy. Additionally, the port site metastases occurred without specimen bag rupture or even extraction of the specimen through the port in question [27]. Meanwhile, Beauvaut *et al.* in a prospective multicenter study reported long-term oncological outcomes after robotic PN for RCC. Among 110 patients was one case of peritoneal carcinomatosis, but no port-site metastasis was observed [28] (Table 1).

Risk factors for recurrence

Previous studies have demonstrated that renal masses smaller than 4 cm are more likely to remain localized to the kidney [32]. In the case of ccRCC and papillary RCC, tumors larger than 3 cm are associated with an increased risk of metastasis [33]. This review explores a range of tumor sizes reported in the literature. The Russo *et al.* study of 58 patients discovered a median tumor size of 5.9 cm [18], while single-patient case reports examining ATR reported tumor size of 2.5 cm, 5.5 cm, and 4 cm, respectively [25-27].
High nuclear grade has been established as an independent risk factor for RCC recurrence [29, 34]. We found that the majority of reported cases of atypical recurrence involve high-grade tumors. Russo *et al.* reported that 43 of 58 (74%) had high grade tumors (grade and 4). Similarly, Dhobada *et al.* noted a grade 3 tumor that resulted in port site metastasis [25], while Pandey *et al.* highlighted a grade 4 tumor that led to ileocecal junction and ovary metastasis ipsilaterally [31].
Sarcomatoid differentiation in RCC is also correlated with an increased rate of recurrence and poor prognosis [35, 36]. This is attributed to several factors, including a high tumor mutational burden especially in cancer driver genes [37], frequent presentation at an advanced or metastatic stage and limited efficacy of targeted therapies [35]. In Russo *et al.*, 10 of 58 patients (17.2%) exhibited sarcomatoid differentiation [18]. Gradecki and Gru reported a case of ccRCC that initially lacked sarcomatoid features but was later presented with a predominantly sarcomatoid pattern upon metastasis to the skin [38]. Although sarcomatoid RCC represents approximately 5% of RCC cases [39], further studies are warranted to investigate sarcomatoid pattern as a potential risk factor for atypical recurrence, given its underlying aggressive nature. Furthermore, the sensitivity of RMB to detect sarcomatoid histology is limited [40]; it has been reported that only about 30-50% of cases ultimately identified at final pathology are detected on RMB [41].
Tumor necrosis has been associated with poor prognosis [42] and is considered an important risk factor for recurrence in RCC [43]. Pandey *et al.* described a case involving ccRCC with tumor necrosis that subsequently metastasized to the ileocolic junction and the ovary [31].
Tumor incision/spillage is a known risk factor for tumor recurrence and metastasis [44]. In a retrospective study by Ito *et al.*, none of the 12 patients with accidental tumor incision during laparoscopic PN developed local or port-site recurrence, suggesting no clear association; however, the small sample size limits definitive conclusions [45]. In contrast, Dhobada *et al.*, noted a case of port-site metastasis following laparoscopic tumor removal using a retrieval bag. This case report highlights the importance of proper and careful use of retrieval bags and demonstrates that retrieval bags may not entirely prevent microscopic tumor

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Table 1. Summary of reported cases and series describing atypical tumor recurrence (ATR) following radical or partial nephrectomy for renal cell carcinoma.

Study	Institution	N	Approach	Location	Stage/grade	Margin status	Histology	Outcome	Other factors
Russo *et al.* [18]	Memorial Sloan Kettering Cancer Center, New York, United States	58	Robotic and Laparoscopic	Numerous Described above	T1 50% T2 10.4% T3 36.2%	Neg 79.3% Pos 17.2%	CCC 67% Sarcomatoid 17% 6.9% Rhabdoid	Overall 5-yr survival from the time of ATR to last follow-up or death was 58.4%	
Castillo *et al.* [23]	Clínica Santa Maria, University of Chile, Chile	1	Laparoscopic	Port Site, peritoneal mass, multiple hepatic lesions	pT1, grade 3	Negative	N/A	Death 17 days after admission	
Masterson & Russo [17]	Memorial Sloan-Kettering Cancer Center, New York, United States	1	Laparoscopic	Port site and intra abdominal	pT1bNXM0	Negative	Papillary RCC	Multiple hepatic and peritoneal recurrences at 12 month follow up	
Greco *et al.* [26]	Martin-Luther-University, Germany	1	Laparoscopic	Port site	PT1a, high grade	Negative	Clear cell papillary carcinoma	No new metastases at 1 year	Intraoperative specimen rupture
Filizoglu *et al.* [29]	Kartal Dr. Lutfi Kirdar Hospital,Turkey	1	N/A	Left nephrectomy bed, pancreas	N/A	N/A	ccRCC	N/A	
Dhobada *et al.* [25]	Institute of Urology, Pune, India	1	Laparoscopic	Port site	T2N0M0	N/A	RCC	N/A	
Kumar *et al.* [24]	Sanjay Gandhi Postgraduate Institute of Medical Sciences, India	2	Laparoscopic	Port site, renal fossa, bony pelvis	T2N1M0 and T3aN1M0	N/A	RCC	N/A	One case converted to open intraoperatively
Ohtake *et al.* [30]	Kainan Hospital, Japan	1	Open	Abdominal wall desmoid tumor	pT3b	N/A	ccRCC	No recurrence or death at undefined follow up	
Pandey *et al.* [31]	Banaras Hindu University, India	1	N/A	ileocolic junction and the ovary	T2N0	Negative	ccRCC	Death 10 months after surgery	Lymphovascular invasion and tumor necrosis present
Song *et al.* [27]	Washington University SOM, United States	1	Robotic	Camera port site	T1aN0M0	N/A	RCC	N/A	
Beauval *et al.* [28]	Multi-Institutional, France	1/110	Robotic	Peritoneal carcinomatosis	pT1a R0	Negative	ccRCC	Death 18 months after surgery	

Note: Summary of reported cases and series describing atypical tumor recurrence (ATR) following radical or partial nephrectomy for renal cell carcinoma. Details include surgical approach, recurrence location, tumor characteristics, margin status, histology, outcomes, and notable intraoperative or pathological findings. CCC = clear cell carcinoma; ccRCC = clear cell renal cell carcinoma; RCC = renal cell carcinoma; N/A = not available.

cell spillage [25].

Conversion from minimally invasive surgery to open surgery is associated with higher recurrence rates in colorectal [46] and liver tumors [47]. In this review, Kumar *et al.* noted that one of 33 patients who underwent conversion to open surgery, displayed port site metastasis [24]. Similarly, Ohtake *et al.*, reported a patient who developed an abdominal wall tumor following a laparoscopic nephrectomy converted to open surgery [30]. In both metastatic cases, severe bleeding was found as the primary reason for conversion.These findings align with previous studies suggesting that the underlying causes of conversion, such as intraoperative complications and more advanced tumor characteristics, are more directly associated with high recurrence rates instead of conversion itself [47, 48].

Discussion

Best practices

Our review shows that the majority of ATR were associated with laparoscopic approaches. This trend may reflect a combination of procedural risk and higher representation in the literature due to increased volume of minimally invasive surgeries and uniform adoption among many urological specialists. The debate between laparoscopic and open surgery continues to evolve. Notably, the landmark Laparoscopic Approach to Cervical Cancer trial demonstrated that minimally invasive radical hysterectomy was associated with significantly lower overall survival compared to open abdominal surgery in early-stage cervical cancer [49]. These findings led to a shift in the standard of care, now recommending open abdominal radical hysterectomy for this patient population [50]. These findings illustrate the importance of surgical technique refinements, especially with respect to specimen handling, morcellation and instrumentation manipulation.

Morcellation is a technique often employed during minimally invasive procedures to facilitate specimen extraction through small incisions. However, in many oncologic surgeries, morcellation carries the risk of disseminating malignant cells, especially if performed without containment [51]. In RCC, a review of 16 cases of port-site metastasis following laparoscopic nephrectomy revealed that seven cases had identifiable technical causes: specimen morcellation (n = 3), failure to use an entrapment bag (n = 2), and tumor rupture (n = 2) [52]. The remaining nine cases had no clear technical etiology. While technical lapses may contribute to port site metastasis formation, the study concluded that underlying tumor biology, such as histologic subtype and metastatic potential, may play a more significant role in these cases. However, the risks associated with technical practices cannot be discounted.

The risks associated with uncontained morcellation have been well-documented in gynecologic oncology, particularly in instances of unsuspected uterine malignancy, where intra-abdominal morcellation has led to tumor dissemination and upstaging. This evidence has led to widespread recommendations against morcellation when malignancy is suspected [53]. Although port site metastasis are incredibly rare, urologic oncologic surgery would most likely benefit from similar cautionary practices, with avoidance of morcellation in high-risk renal masses and mandatory use of containment systems when specimen fragmentation is necessary. Although a few studies from the early 2000s suggest that morcellation was an effective minimally invasive surgical option for T1-2 and low grade RCC when performed carefully with proper specimen bagging and no intra-abdominal spillage, with Wu *et al.* (mean follow up 21 months) [54] and Lesani *et al.* (mean follow up 14.3 months) [55] finding no increased recurrence rates. This practice has largely been abandoned due to forfeiture of accurate staging, grading, margin status, and detection of aggressive histologic variants [54-61].

Cases related to entrapment bags may have some correlation with port site metastasis [52], however as mentioned above, the potential limitation of microscopic tumor cell spillage cannot be completed prevented by use of retrieval bags [25].

In addition to morcellation and bag use, prior reviews have additional recommendations to reduce risk of urological port site metastasis. These usually arise from manipulation of surgical instruments, which can be mitigated by sufficient technical preparation, avoidance of laparoscopic surgery with ascites present, proper trocar fixation without gas leakage, avoidance of tumor boundary, drain placement if needed before abdominal deflation, and thorough irrigation of instrumentation and port site wounds (including techniques for iodine irrigation) [51], much of which should be considered as part of standardized practice.

Notably lacking from the literature are reports of ATR following nephrectomy in the metastatic setting. Theoretically, distant metastasis and the presence of circulating tumor DNA with potential hematogenous seeding during surgery, along with the previously mentioned mechanisms such as tumor staging, spillage, necrosis, and high nuclear grade, might predispose to a higher rate of recurrence with cytoreductive nephrectomy compared to surgery for localized disease. In addition, the use of systemic immune therapies, such as tyrosine kinase inhibitors (TKIs) and immune checkpoint inhibitors (ICIs), prior to cytoreductive nephrectomy is currently being studied [62, 63] and their respective roles in reducing tumor size through tissue necrosis. Their role in tissue necrosis may lead to increased friability during surgical resection and a higher risk of seeding and ATR. To date, this has not been reported. Interesting to consider is the rate of such ATR in the setting of preoperative/induction targeted molecular therapy, such as TKIs, which exert limited effects only during dosing, versus ICIs, which can exert prolonged effects due to immune system priming and neoantigenicity [64]. Certainly, an improved understanding of the potential for ATR becomes increasingly important in guiding the sequencing of systemic therapy prior to or after cytoreductive surgery, as it not only influences metastatic progression but may also influence rates of ATR.

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Future directions

The growing recognition of ATR following highlights several key areas for future investigation. First, the true incidence of ATR remains unclear and may be underrecognized due to inconsistent reporting practices and lack of long-term surveillance protocols tailored to detect these patterns. Prospective multicenter registries with standardized definitions of ATR and structures follow-up are needed to more accurately estimate incidence and evaluate oncologic outcomes.

Second, while our review suggests a higher prevalence of ATR among laparoscopic and robotic approaches [17, 23, 27], existing data are limited by publication bias and retrospective design. Comparative studies with adequate adjustment for cofounders including tumor characteristics, surgical technique, and use of containment systems are essential to determine whether minimally invasive approaches have an increased risk for ATR. In addition, specific ATR rates in the metastatic setting after induction ICI and TKI therapy followed by cytoreductive nephrectomy must be tracked and analyzed moving forward.

Third, given the heterogeneous biological behavior of RCC, there is a need to identify molecular or imaging biomarkers that can stratify patients by risk of ATR. Future studies should explore the utility of circulating tumor DNA, radiomics, and advanced molecular profiling to predict ATR and guide perioperative decision-making [37].

Finally, integrating evidence-based best practices into surgical training and perioperative protocols may reduce recurrence risk. Emphasis on specimen handling, avoidance of tumor morcellation without containment, and uniform use of retrieval bags should be part of standard operating procedures, especially in high-grade or sarcomatoid RCC. The development of technical guidelines and quality metrics for cytoreductive nephrectomy in the metastatic setting, especially in the context of the complete responses seen in the era of IO-IO and IO-TKI therapy, may enhance safety and promote superlative oncologic outcomes.

Conclusions

ATR after RN is an uncommon but clinically significant event, most often associated with high-grade tumors, sarcomatoid features, and minimally invasive approaches. While technical factors such as tumor spillage and morcellation may contribute, the multifactorial nature of ATR, including tumor biology and surgical technique, highlights the complexity of its pathogenesis. Although most available data are derived from nephrectomy for localized disease, the expanding role of CN in the management of mRCC highlights the need for heightened awareness of ATR in this population. Given the potential impact of emerging systemic therapies on tumor friability and recurrence patterns, further investigation into ATR following CN is warranted. Standardization of reporting, adherence to oncologic principles, and integration of risk-reduction strategies into surgical practice will be essential for optimizing outcomes in both localized and metastatic RCC.

Declarations

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References

1. Bhindi B, Abel E, Albiges L, Bensalah K, Boorjian S, Daneshmand S, *et al.* Systematic review of the role of cytoreductive nephrectomy in the targeted therapy era and beyond: an individualized approach to metastatic renal cell carcinoma. *Eur Urol*, 2019, 75(1): 111-128. [Crossref]
2. Nolazco J, & Chang S. Role of surgery in metastatic renal cell carcinoma. *Hematol Oncol Clin North Am*, 2023, 37(5): 893-905. [Crossref]
3. Hsiang W, Kenney P, & Leapman M. Redefining the role of surgical management of metastatic renal cell carcinoma. *Curr Oncol Rep*, 2020, 22(4): 35-49. [Crossref]
4. Patel H, Karam J, & Allaf M. Surgical management of advanced kidney cancer: the role of cytoreductive nephrectomy and lymphadenectomy. *J Clin Oncol*, 2018: Jco2018790246. [Crossref]
5. Naito S, Kato T, & Tsuchiya N. Surgical and focal treatment for metastatic renal cell carcinoma: a literature review. *Int J Urol*, 2022, 29(6): 494-501. [Crossref]
6. Sooriakumaran P, Kommu S, Anderson C, & Rane A. Port-site metastasis after laparoscopic surgery: what causes them and what can be done to reduce their incidence? *BJU Int*, 2009, 103(9): 1150-1153. [Crossref]
7. Pyrgidis N, Schulz G, Stief C, Blajan I, Ivanova T, Graser A, *et al.* Surgical trends and complications in partial and radical nephrectomy: results from the GRAND study. *Cancers*, 2023, 16(1): 97-110. [Crossref]
8. Auffenberg G, Curry M, Gennarelli R, Blum K, Elkin E, & Russo P. Comparison of cancer-specific outcomes following minimally-invasive and open surgical resection of early-stage kidney cancer from a national cancer registry. *J Urol*, 2020. [Crossref]
9. F DIB, Rodriguez Peñaranda N, Marmiroli A, Longoni M, Falkenbach F, Le Q, *et al.* Total hospital cost of robot-assisted approach in major urological cancer surgeries. *Minerva urol nephr*, 2025, 77(2): 217-225. [Crossref]
10. Mullins J, Feng T, Pierorazio P, Patel H, Hyams E, & Allaf M. Comparative analysis of minimally invasive partial ne-

phrectomy techniques in the treatment of localized renal tumors. *Urology*, 2012, 80(2): 316-321. [Crossref]

11. Tyson M, & Chang S. Optimal surveillance strategies after surgery for renal cell carcinoma. *J Natl Compr Canc Netw*, 2017, 15(6): 835-840. [Crossref]
12. Geisbush T, Dymon Z, Gabriel M, & Yedavalli V. A multimodal and pathological analysis of a renal cell carcinoma metastasis to the thyroid gland 11 years post nephrectomy. *J Radiol Case Rep*, 2019, 13(4): 1-9. [Crossref]
13. Smart A, Wynne M, Baraban E, Ged Y, & Smith A. Metastasis to the bladder: a rare site of recurrence of renal cell carcinoma. *Case Rep Urol*, 2022, 2022: 4339270. [Crossref]
14. Ali S, Chughtai H, Alali F, Diaczok B, & Verardi M. Wrist drop: an atypical presentation of renal cell carcinoma. *Am J Med Sci*, 2011, 342(2): 170-173. [Crossref]
15. Martínez-Rodríguez R, Rodríguez-Escovar F, Bujons Tur A, Maroto P, Palou J, & Villavicencio H. Skin metastasis during follow-up of a clear cell renal carcinoma. *Arch Esp Urol*, 2008, 61(1): 80-82. [Crossref]
16. Rodríguez Fernández E, Cardo A, Subirá Ríos D, Cancho Gil M, González García F, Herranz Amo F, *et al.* Peritoneal carcinomatosis after partial nephrectomy for renal cell carcinoma: our experience and literature review. *Actas Urol Esp*, 2022, 46(8): 481-486. [Crossref]
17. Masterson T, & Russo P. A case of port-site recurrence and locoregional metastasis after laparoscopic partial nephrectomy. *Nat Clin Pract Urol*, 2008, 5(6): 345-349. [Crossref]
18. Russo P, Blum K, Weng S, Graafland N, & Bex A. Outcomes for atypical tumor recurrences following minimally invasive kidney cancer operations. *Eur Urol Open Sci*, 2022, 40: 125-132. [Crossref]
19. Brokelman W, Lensvelt M, Rinkes I, Klinkenbijl J, & Reijnen M. Peritoneal changes due to laparoscopic surgery. *Surgical Endoscopy*, 2011, 25(1): 1-9. [Crossref]
20. Neuhaus S, & Watson D. Pneumoperitoneum and peritoneal surface changes: a review. *Surg Endosc*, 2004, 18(9): 1316-1322. [Crossref]
21. Tsivian A, & Sidi A. Port site metastases in urological laparoscopic surgery. *J Urol*, 2003, 169(4): 1213-1218. [Crossref]
22. Brookman-May S, May M, Shariat S, Novara G, Zigeuner R, Cindolo L, *et al.* Time to recurrence is a significant predictor of cancer-specific survival after recurrence in patients with recurrent renal cell carcinoma--results from a comprehensive multi-centre database (CORONA/SATURN-Project). *BJU Int*, 2013, 112(7): 909-916. [Crossref]
23. Castillo O, Vitagliano G, Díaz M, & Sánchez-Salas R. Port-site metastasis after laparoscopic partial nephrectomy: case report and literature review. *J Endourol*, 2007, 21(4): 404-407. [Crossref]
24. Kumar V, Mandhani A, Srivastava A, Ansari M, Singh U, & Kapoor R. Port site metastasis after laparoscopic radical nephrectomy: a single-center experience. *Indian journal of cancer*, 2012, 49(1): 102-106. [Crossref]
25. Dhobada S, Patankar S, & Gorde V. Case report: port-site metastasis after laparoscopic radical nephrectomy for renal-cell carcinoma. *J Endourol*, 2006, 20(2): 119-122; discussion 122. [Crossref]
26. Greco F, Wagner S, Reichelt O, Inferrera A, Lupo A, Hoda R, *et al.* Huge isolated port-site recurrence after laparoscopic partial nephrectomy: a case report. *Eur Urol*, 2009, 56(4): 737-739. [Crossref]
27. Song J, Tanagho Y, Kim E, Abbosh P, Vemana G, & Figenshau R. Camera-port site metastasis of a renal-cell carcinoma after robot-assisted partial nephrectomy. *J Endourol*, 2013, 27(6): 732-739. [Crossref]
28. Beauval J, Peyronnet B, Benoit T, Cabarrou B, Seisen T, Roumiguié M, *et al.* Long-term oncological outcomes after robotic partial nephrectomy for renal cell carcinoma: a prospective multicentre study. *World J Urol*, 2018, 36(6): 897-904. [Crossref]
29. Liu F, Wang L, Meagher M, Afari J, Saitta C, Dhanji S, *et al.* Predictive factors for recurrence and outcomes in T1a renal cell carcinoma: analysis of the INMARC (International marker consortium for renal cancer) database. *Urologic Oncology: Seminars and Original Investigations*, 2024, 42(10): 333.e321-333.e331. [Crossref]
30. Ohtake S, Namura K, Fujikawa A, Sawada T, Ohta J, Moriyama M, *et al.* A case of abdominal wall desmoid tumor after radical nephrectomy for renal cancer. *Hinyokika Kiyo*, 2015, 61(9): 353-357.
31. Pandey M, Ramasamy M, & Shukla M. Unusual progression of renal cell carcinoma with carcinomatosis peritoneii and Krukenberg tumour and alopecia with sunitinib therapy in young female. *World J Surg Oncol*, 2018, 16(1): 23-40. [Crossref]
32. Kurban L, Vosough A, Jacob P, Prasad D, Lam T, Scott N, *et al.* Pathological nature of renal tumors - does size matter? *Urol Ann*, 2017, 9(4): 330-334. [Crossref]
33. Monda S, Lui H, Pratsinis M, Chandrasekar T, Evans C, & Dall'Era M. The metastatic risk of renal cell carcinoma by primary tumor size and subtype. *Eur Urol Open Sci*, 2023, 52: 137-144. [Crossref]
34. van der Mijn J, Al Hussein Al Awamlh B, Islam Khan A, Posada-Calderon L, Oromendia C, Fainberg J, *et al.* Validation of risk factors for recurrence of renal cell carcinoma: results from a large single-institution series. *PLoS One*, 2019, 14(12): e0226285. [Crossref]
35. Lebacle C, Pooli A, Bessede T, Irani J, Pantuck A, & Drakaki A. Epidemiology, biology and treatment of sarcomatoid RCC: current state of the art. *World J Urol*, 2019, 37(1): 115-123. [Crossref]
36. Tully K, Berg S, Paciotti M, Janisch F, Reese S, Noldus J, *et al.* The natural history of renal-cell carcinoma with sarcomatoid differentiation, a stage-by-stage analysis. *Clin Genitourin Cancer*, 2023, 21(1): 63-68. [Crossref]
37. Bi M, Zhao S, Said J, Merino M, Adeniran A, Xie Z, *et al.* Genomic characterization of sarcomatoid transformation in clear cell renal cell carcinoma. *Proceedings of the National Academy of Sciences*, 2016, 113(8): 2170-2175. [Crossref]
38. Gradecki S, & Gru A. An unusual case of sarcomatoid renal cell carcinoma presenting in the skin by direct extension at a laparoscopic port site. *J Cutan Pathol*, 2020,

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47(7): 617-620. [Crossref]
39. Shuch B, Bratslavsky G, Linehan W, & Srinivasan R. Sarcomatoid renal cell carcinoma: a comprehensive review of the biology and current treatment strategies. *Oncologist*, 2012, 17(1): 46-54. [Crossref]
40. Shuch B, Amin A, Armstrong A, Eble J, Ficarra V, Lopez-Beltran A, *et al.* Understanding pathologic variants of renal cell carcinoma: distilling therapeutic opportunities from biologic complexity. *Eur Urol*, 2015, 67(1): 85-97. [Crossref]
41. Kapur P, Setoodeh S, Araj E, Yan J, Malladi V, Cadeddu J, *et al.* Improving renal tumor biopsy prognostication with BAP1 analyses. *Arch Pathol Lab Med*, 2022, 146(2): 154-165. [Crossref]
42. Zhang L, Zha Z, Qu W, Zhao H, Yuan J, Feng Y, *et al.* Tumor necrosis as a prognostic variable for the clinical outcome in patients with renal cell carcinoma: a systematic review and meta-analysis. *BMC Cancer*, 2018, 18(1): 870-884. [Crossref]
43. Ito K, Seguchi K, Shimazaki H, Takahashi E, Tasaki S, Kuroda K, *et al.* Tumor necrosis is a strong predictor for recurrence in patients with pathological T1a renal cell carcinoma. *Oncol Lett*, 2015, 9(1): 125-130. [Crossref]
44. Curet M. Port site metastases. *Am J Surg*, 2004, 187(6): 705-712. [Crossref]
45. Ito H, Makiyama K, Kawahara T, Osaka K, Izumi K, Yokomizo Y, *et al.* Impact of accidental tumor incision during laparoscopic partial nephrectomy on the oncologic and clinical outcomes. *Clin Genitourin Cancer*, 2016, 14(4): e291-297. [Crossref]
46. Clancy C, O'Leary D, Burke J, Redmond H, Coffey J, Kerin M, *et al.* A meta-analysis to determine the oncological implications of conversion in laparoscopic colorectal cancer surgery. *Colorectal Dis*, 2015, 17(6): 482-490. [Crossref]
47. Troisi R, Montalti R, Van Limmen J, Cavaniglia D, Reyntjens K, Rogiers X, *et al.* Risk factors and management of conversions to an open approach in laparoscopic liver resection: analysis of 265 consecutive cases. *HPB (Oxford)*, 2014, 16(1): 75-82. [Crossref]
48. Wu B, Wang W, Hao G, & Song G. Effect of cancer characteristics and oncological outcomes associated with laparoscopic colorectal resection converted to open surgery: a meta-analysis. *Medicine*, 2018, 97(50): e13317. [Crossref]
49. Ramirez P, Frumovitz M, Pareja R, Lopez A, Vieira M, Ribeiro R, *et al.* Minimally invasive versus abdominal radical hysterectomy for cervical cancer. *N Engl J Med*, 2018, 379(20): 1895-1904. [Crossref]
50. Koh W, Abu-Rustum N, Bean S, Bradley K, Campos S, Cho K, *et al.* Cervical cancer, Version 3.2019, NCCN clinical practice guidelines in oncology. *J Natl Compr Canc Netw*, 2019, 17(1): 64-84. [Crossref]
51. Kadi N, Isherwood M, Al-Akraa M, & Williams S. Port-site metastasis after laparoscopic surgery for urological malignancy: forgotten or missed. *Adv Urol*, 2012, 2012: 609531. [Crossref]
52. Song J, Kim E, Mobley J, Vemana G, Tanagho Y, Vetter J, *et al.* Port site metastasis after surgery for renal cell carcinoma: harbinger of future metastasis. *J Urol*, 2014, 192(2): 364-368. [Crossref]
53. Zapardiel I, Boria F, Halaska M, & De Santiago J. Laparoscopic power morcellation: techniques to avoid tumoral spread. *J Minim Invasive Gynecol*, 2021, 28(8): 1442-1443. [Crossref]
54. Wu S, Lesani O, Zhao L, Johnston W, Wolf J, Jr., Clayman R, *et al.* A multi-institutional study on the safety and efficacy of specimen morcellation after laparoscopic radical nephrectomy for clinical stage T1 or T2 renal cell carcinoma. *J Endourol*, 2009, 23(9): 1513-1518. [Crossref]
55. Lesani O, Zhao L, Han J, Okotie O, Desireddi N, Johnston W, *et al.* Safety and efficacy of laparoscopic radical nephrectomy with manual specimen morcellation for stage cT1 renal-cell carcinoma. *J Endourol*, 2008, 22(6): 1257-1260. [Crossref]
56. Pautler S, Hewitt S, Linehan W, & Walther M. Specimen morcellation after laparoscopic radical nephrectomy: confirmation of histologic diagnosis using needle biopsy. *J Endourol*, 2002, 16(2): 89-92. [Crossref]
57. Landman J, Lento P, Hassen W, Unger P, & Waterhouse R. Feasibility of pathological evaluation of morcellated kidneys after radical nephrectomy. *J Urol*, 2000, 164(6): 2086-2089.
58. Fentie D, Barrett P, & Taranger L. Metastatic renal cell cancer after laparoscopic radical nephrectomy: long-term follow-up. *J Endourol*, 2000, 14(5): 407-411. [Crossref]
59. Landman J, Venkatesh R, Kibel A, & Vanlangendonck R. Modified renal morcellation for renal cell carcinoma: laboratory experience and early clinical application. *Urology*, 2003, 62(4): 632-634; discussion 635. [Crossref]
60. Cohen D, Matin S, Steinberg J, Zagone R, & Wood C. Evaluation of the intact specimen after laparoscopic radical nephrectomy for clinically localized renal cell carcinoma identifies a subset of patients at increased risk for recurrence. *J Urol*, 2005, 173(5): 1487-1490; discussion 1490-1481. [Crossref]
61. Barrett P, Fentie D, & Taranger L. Laparoscopic radical nephrectomy with morcellation for renal cell carcinoma: the Saskatoon experience. *Urology*, 1998, 52(1): 23-28. [Crossref]
62. do Amaral P, Beckermann K, Gordetsky J, Chang S, Joyce D, Schaffer K, *et al.* Clinical and pathological outcomes of deferred nephrectomy in patients with metastatic and locally advanced RCC after immune checkpoint inhibitors. *Oncologist*, 2025, 30(4): oyaf004. [Crossref]
63. Gunenc D, Issa W, Gerald T, Zhou Q, Zhang S, Ibezue I, *et al.* Pathological response and outcomes in patients with metastatic renal cell carcinoma (mRCC) receiving immunotherapy-based therapies and undergoing deferred cytoreductive nephrectomy (CN). *Clin Genitourin Cancer*, 2024, 22(5): 102177. [Crossref]
64. Daly R, Scott A, Klein O, & Ernst M. Enhancing therapeutic anti-cancer responses by combining immune checkpoint and tyrosine kinase inhibition. *Mol Cancer*, 2022,

21(1): 189-201. [Crossref]

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Table S1. Summary of reported cases and series.

Author/year	Study design	Population	Intervention/focus	Key outcomes	Main findings
Bhindi *et al.*, 2019	Systematic review	Patients with metastatic RCC	Role of cytoreductive nephrectomy in era of targeted therapy	Overall Survival	Cytoreductive nephrectomy should not be uniformly applied; patient selection is key.
Nolazco & Chang, 2023	Narrative review	Patients with metastatic RCC	Role of surgery in metastatic setting	n/a	Surgery remains relevant for select patients with good performance status and limited disease burden.
Hsiang *et al.*, 2020	Narrative review	Patients with metastatic RCC	Role of surgery in metastatic setting	n/a	Initial systemic therapy is non-inferior to surgery in intermediate/poor-risk groups.
Patel *et al.*, 2018	Review	Advanced RCC	Cytoreductive nephrectomy & lymphadenectomy	n/a	Surgery selective for favorable-risk; limited benefit in higher-risk.
Naito *et al.*, 2022	Literature review	Metastatic RCC	Surgery & focal therapies	OS, local control, timing	Deferred CN & metastasectomy show potential but selective.
Sooriakumaran *et al.*, 2009	Literature review	Lap kidney surgery	Port-site metastasis mechanisms	Prevention strategies	Rare, prevent with careful specimen handling.
Pyrgidis *et al.*, 2023	Retrospective cohort	RCC nephrectomy patients	Surgical trends & complications	Morbidity, outcomes	Radical nephrectomy increases perioperative morbidity.
Auffenberg *et al.*, 2020	Retrospective cohort	Early-stage RCC	MIS *vs* open resection	OS, DSS	No survival difference by approach.
Di Bello *et al.*, 2025	Retrospective cohort (cost)	RA *vs.* open urologic surgeries	Cost analysis	Hospital cost	Robot-assisted increases cost.
Mullins *et al.*, 2012	Retrospective cohort	Localized RCC	Robotic PN *vs* lap PN	Perioperative & oncologic	Robotic PN shorter ischemia, same complications.
Tyson & Chang, 2017	Narrative review	Localized RCC	Surveillance strategies	Recurrence	20% recur post-surgery, half in 2 years.
Geisbush *et al.*, 2019	Case report	RCC	Thyroid metastasis	n/a	Very late recurrence → need long follow-up.
Smart *et al.*, 2022	Case report	RCC	Bladder metastasis	n/a	Rare site of recurrence.
Ali SH *et al.*, 2011	Case report	RCC	Radial nerve palsy metastasis	n/a	Unusual neuro manifestation of RCC.
Martínez-Rodríguez *et al.*, 2008	Case report	RCC	Skin metastasis	n/a	Cutaneous spread rare, poor prognosis.
Rodríguez Fernández *et al.*, 2022	Case series + review	RCC	Peritoneal carcinomatosis post-surgery	Clinical presentation	Rare spread, technique matters.
Masterson & Russo, 2008	Case report	Lap PN patient	Port-site recurrence	n/a	Port-site seeding risk.
Russo *et al.*, 2022	Retrospective cohort	115 RCC with atypical recurrences	Unusual recurrence patterns	Survival	Atypical recurrences poor outcomes.
Brokelman *et al.*, 2011	Review + experimental	Lap surgery patients	Pneumoperitoneum peritoneal changes	Histology	Changes may favor tumor seeding.
Neuhaus & Watson, 2004	Review	Lap surgery	Pneumoperitoneum effects	Mechanisms	Peritoneum altered, potential risk.

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Table S1 continued.

Author/Year	Study Design	Population	Intervention/Focus	Key Outcomes	Main Findings
Neuhaus & Watson, 2004	Review	Lap surgery	Pneumoperitoneum effects	Mechanisms	Peritoneum altered, potential risk.
Tsivian & Sidi, 2003	Review	Urologic laparoscopy	Port-site metastases	Reported cases	Rare. Due to tumor spillage, pneumoperitoneum, instrument contamination
Brookman-May *et al.*, 2013	Multicenter database	1034 RCC with recurrence	Time to recurrence	CSS	Early recurrence → worse CSS.
Castillo *et al.*, 2007	Case + review	RCC	Port-site metastasis	n/a	Port-site metastasis is rare but possible
Kumar *et al.*, 2012	Case series	3 RCC patients	Port-site metastasis after lap radical nephrectomy	n/a	Evidence of seeding.
Dhobada *et al.*, 2006	Case	Lap kidney surgery	Port-site metastasis mechanisms	Prevention strategies	Rare, prevent with careful specimen handling.
Greco *et al.*, 2009	Case	Port-site metastasis after lap nephrectomy	n/a	Demonstrates seeding.	Radical nephrectomy increases perioperative morbidity.
Song *et al.*, 2013	Case	Large port-site recurrence	n/a	Rare, aggressive local recurrence.	No survival difference by approach.
Beauval *et al.*, 2018	Prospective multicenter	1240 RCC patients	Robotic PN long-term	Oncologic outcomes	Low recurrence, good control.
Kurban *et al.*, 2017	Retrospective pathology	RCC	Tumor size vs histology	Pathology correlation	Larger → more aggressive, but not sole predictor.
Monda *et al.*, 2023	Database	> 4000 RCC patients	Tumor size & subtype	Metastatic risk	Both size + subtype predict risk.
van der Mijn *et al.*, 2019	Retrospective	RCC	Recurrence risk validation	RFS, OS	Grade, stage, and size predictive.
Liu *et al.*, 2024	Database	T1a RCC	Predictors of recurrence	Recurrence, OS	Beyond size, grade & histology important.
Pandey *et al.*, 2018	Case	RCC	Radial nerve palsy metastasis	n/a	Unusual neuro manifestation of RCC.
Lebacle *et al.*, 2019	Review	RCC	Sarcomatoid biology	Prognosis/treatment	Aggressive, multimodal needed.
Tully *et al.*, 2023	Retrospective cohort	Sarcomatoid RCC	Stage-based analysis	CSS outcomes	Stage key to prognosis.
Bi *et al.*, 2016	Genomic study	ccRCC w/ sarcomatoid	Mutations	Pathways	TP53, NF2 alterations linked to Sarcomatoid.
Gradecki & Gru, 2020	Case report	RCC	Sarcomatoid RCC at port-site	n/a	rare direct extension to port-site skin.
Shuch *et al.*, 2012	Review	Sarcomatoid RCC	Biology & strategy	Prognostic insight	Dedifferentiated RCC, poor prognosis.
Shuch *et al.*, 2015	Review	RCC variants	Histologic subtypes	Classification	Variants guide therapy/prognosis.

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Table S1 continued.

Author/Year	Study Design	Population	Intervention/Focus	Key Outcomes	Main Findings
Kapur *et al.*, 2022	Pathology	183 RCC biopsies	BAP1 biomarker	Prognostic accuracy	BAP1 improves biopsy-based prognosis.
Zhang *et al.*, 2018	Systematic review & meta-analysis	RCC patients (multiple studies)	Tumor necrosis as prognostic variable	OS, CSS, RFS	Necrosis strongly predicts poor prognosis.
Ito *et al.*, 2015	Retrospective cohort	94 patients with pT1a RCC	Necrosis in specimens	Recurrence	Necrosis predicts recurrence in small RCC.
Curet, 2004	Review	Cancer laparoscopy pts	Port site metastasis	Incidence	Rare but possible, prevention critical.
Ito *et al.*, 2016	Retrospective cohort	128 lap PN	Accidental tumor incision	Recurrence, complications	No significant prognosis change.
Clancy *et al.*, 2015	Meta-analysis	Colorectal cancer	Conversion lap→open	OS, DFS	Conversion worsens oncologic outcomes.
Troisi *et al.*, 2014	Retrospective (265)	Liver resection	Conversion risks	Complications, survival	Conversion linked to more blood loss, longer stay, no survival impact.
Ohtake *et al.*, 2015	Case	Early-stage RCC	MIS vs open resection	OS, DSS	No survival difference by approach.
Report	Post RCC nephrectomy	Abdominal wall desmoid	Clinical course	Rare tumor after RCC surgery.	Robot-assisted increases cost.
Wu *et al.*, 2018	Meta-analysis	Colorectal cancer	Lap→open conversion	Oncologic outcomes	Conversion linked to poor prognosis.
Ramirez *et al.*, 2018	RCT	Cervical cancer	Minimally invasive vs open hysterectomy	DFS, OS	Minimally invasive had worse survival.
Kadi *et al.*, 2012	Review	Urologic tumors	Port-site metastasis	Incidence	Very rare, uncertain mechanisms.
Song *et al.*, 2014	Multi-institution	RCC	Port-site metastasis	Prognosis	Harbinger of systemic spread.
Zapardiel *et al.*, 2021	Technical note	Gynecologic oncology	Power morcellation	Spread prevention	Containment techniques needed.
Wu *et al.*, 2009	Retrospective	RCC T1-2	Morcellation	Recurrence	Safe, diagnosis preserved.
Lesani *et al.*, 2008	Case Series	cT1 RCC	Manual morcellation	Safety, OS	Safe with outcomes equivalent.
Pautler *et al.*, 2002	Case	Lap PN patient	Port-site recurrence	n/a	Port-site seeding risk.
Landman *et al.*, 2000	Feasibility	RCC	Pathology of morcellated specimens	Diagnosis accuracy	Morcellation allows adequate diagnosis.
Fentie *et al.*, 2000	Case/long-term	RCC lap nephrectomy	Outcomes	Metastasis	Rare, long-term metastasis post-lap.

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Table S1 continued.

Author/Year	Study Design	Population	Intervention/Focus	Key Outcomes	Main Findings
Landman *et al.*, 2003	Lab/early clinical	RCC	Modified morcellation	Feasibility	Limits tumor spillage.
Cohen *et al.*, 2005	Retrospective	RCC	Intact vs morcellated	Recurrence risk	Intact helps ID high-risk recurrence.
Barrett *et al.*, 1998	Early series	RCC	Lap nephrectomy + morcellation	Outcomes	Safe, effective early approach.
do Amaral *et al.*, 2025	Retrospective, multi-center	Advanced RCC	Deferred nephrectomy after ICI	Path/clinical outcomes	Safe and effective post-ICI.
Gunenc *et al.*, 2024	Retrospective cohort	mRCC on immunothersapy	Deferred CN	Pathology, survival	Positive response in well-selected patients.
Daly *et al.*, 2022	Review	RCC therapy development	ICI + TKI combo	Synergy	Combined therapy enhances responses.

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