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Original Article

Peritoneal recurrence following nephrectomy for localized renal cancer: A multicenter European real-world analysis of incidence, pattern and treatment (PEMET study−UroCCR 124)

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Abstract

Background: Peritoneal recurrence (PREC) following nephrectomy for localized renal cancer (RCC) is rare. Our objective was to report a multicenter analysis of PREC to analyze incidence, treatment, survival and risk factors.

Methods: Between 1987 and 2023, patients with PREC following radical or partial nephrectomy (PN) for localized RCC across ten European institutions (UroCCR, NKI, IRCCS, Foch and Gustave Roussy centers) were included. PREC patterns were defined as isolated PREC (iPREC) and PREC associated with other metastatic sites (mPREC). The main objective was to evaluate PREC incidence (n PREC / n RCC surgeries). Secondary objectives were to assess PREC treatments, patients survival and risk factors associated with iPREC as compared to mPREC.

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Results: We included 117 patients with PREC, including 35 iPREC (30%) and 82 mPREC (70%). PREC incidence was 0.88%. Compared to mPREC, iPREC was significantly associated with PN (OR 4.1, 95% CI [1.7−9.5], $P = 0.001$), minimally invasive surgery (MIS) (OR 3.3, 95% CI [1.3−8.2], $P = 0.007$), and lower Leibovich risk scores (OR 4.6, 95% CI [1.9−11.0], $P = 0.001$). In multivariable analysis, Leibovich score remained significant (OR 3.3, 95% CI [1.2−8.8], $P = 0.016$). Treatment was mainly systemic (66.7%). Surgical treatment was performed in 11 iPREC cases, with 10 patients remaining progression-free at a median follow-up of 54 months. Overall survival was significantly better in iPREC group ($P = 0.007$).

Conclusions: PREC incidence was below 1%. Our results suggest 2 distinct mechanisms. One involves local spread, potentially favored by MIS and PN, while the other corresponds to a metastatic dissemination driven by tumor aggressiveness. iPREC appears to have better prognosis as compared to mPREC and be effectively treated with surgery.

Keywords: Carcinosis; Kidney cancer; Metastatic; Peritoneal; Recurrence; Renal cell carcinoma; Surgery

1. Introduction

Renal cell carcinoma (RCC) ranks third among urological cancers and its incidence is growing worldwide [1,2]. Nephrectomy is the standard treatment for localized renal cancer, with the advent of partial nephrectomy and mini-invasive procedures when technically feasible [3,4]. Almost one third of patients with surgically treated localized RCC will eventually recur with metastatic progression, typically in lung, liver, adrenal gland, lymph nodes, bone or brain [5−7]. However, RCC comprises heterogenous groups of cancers whose characteristics and patterns of recurrences are different [6,8]. Peritoneal recurrence (PREC) is a rare event in urological cancers [9−11]. Its mechanism is unknown and its management remains challenging.

We aimed to evaluate the incidence, presentation, treatment and outcome of PREC following nephrectomy for localized RCC in a European multicenter cohort.

2. Methods

2.1. Data source

The PEMET study was designed in collaboration with the Cancerology Committee of the French Association of Urology. Data were collected from 10 European uro-oncological referral centers adhering to contemporary prospective databases on surgically treated localized RCC (UroCCR including 6 French University Centers (Bordeaux, Angers, Rouen, Rennes, Caen, Toulouse), IRCCS San Raffaele Hospital (Segrate/Milan, Italy), The Netherlands Cancer Institute (NKI) (Amsterdam, the Netherlands), Foch University Hospital (Suresnes, France) and Gustave Roussy Institute (Villejuif, France). UroCCR project (NCT03293563), was IRB-approved and obtained CNIL decision (no. DT-2024-027, December 31, 2024) authorizing the Bordeaux University Hospital Center to implement automated data processing for the purpose of creating a health data warehouse, called "UroCCR" (authorization request no. 2,231,991). The multicentric prospective database was approved by Ethics Committee (DC 2012/108). IRCCS database was approved by the IRCCS San Raffaele Hospital Ethical Committee (protocol URBBAN-version 4 29/08/2007 - Ospedale San Raffaele di Milano). The NKI database was IRB-approved under number IRBd21-203. All patients received oral and written information about the objectives and methodology of the databases and written consent was obtained. PEMET study was approved by Ethic Committee (AFU-CERU_2024-038). Period of inclusion ranged from 1987 to 2023.

2.2. Patients

All patients presenting with PREC following radical (RN) or partial nephrectomy (PN) for localized RCC (defined as cTany, cN0, cM0) were included. Peritoneal metastasis synchronous with RCC diagnosis were excluded. Peritoneal recurrence was defined as any peritoneal nodule measuring more than 1 cm with contrast enhancement on MRI or CT scan, located within the peritoneal cavity, including deposits on the digestive tract, mesentery, or the parietal peritoneal wall. Follow-up protocols were at the discretion of physicians, following national or European guidelines according to risk stratification [3,4]. Patients demographics, surgical approach and RCC characteristics, metastatic timing and pattern, PREC incidence, treatment and follow-up were assessed. We defined 2 different PREC patterns at the time of recurrence diagnosis: isolated PREC (iPREC), and PREC associated with other metastatic sites (mPREC). iPREC was defined as patient with only peritoneal recurrence at time of progression following surgery for localized RCC (no other metastatic site) as compared to mPREC which included patients with peritoneal recurrence associated with other metastatic sites. Patients initially classified as iPREC at recurrence diagnosis who subsequently developed additional metastases during follow-up remained categorized as iPREC based on their initial presentation.

2.3. Outcomes

The main objective was to evaluate PREC incidence in a population of patients who had surgery for localized RCC.

Incidence was calculated as number of PREC / number of patients who had surgery for localized RCC and reported in percentage. Secondary objective was to assess risk factors associated with iPREC as compared to mPREC. Finally, last objectives were to describe the treatments offered in cases of iPREC and mPREC, as well as patients survival.

The incidence of PREC was calculated based on the 3 databases for which we knew the exact number of renal surgeries for localized kidney cancer performed during the study period (UroCCR, NKI, IRCCS).

2.4. Statistical analyses

Statistical analyses were carried out with SPSS 16.0 software. Chi-2 and Fischer tests were carried out to assess the qualitative variables and Mann-Whitney test for quantitative variables. These tests were bilateral with a level of significance (p) set at *0.05*. Survival curves were analyzed according to the Kaplan Meyer method. Kaplan-Meier survival analysis with log-rank tests was used to compare time-to-event outcomes (overall survival (OS)) between groups. Univariate and multivariate Cox proportional hazards models were used to identify independent factors associated with PREC. Given the limited number of events, the multivariable model was restricted to 3 covariates of primary interest: surgical approach (minimally invasive vs. open), histological subtype, and tumor aggressiveness (as reflected by the Leibovich score). Due to the low number of patients with iPREC and the need to limit the number of factors in the multivariable analysis to 3, we chose not to include grade, surgical margin and T stage. Instead, we included the 2018 Leibovich score, which integrates all histoprognostic factors [12].

3. Results

We included a total of 117 patients who developed PREC during postoperative follow-up. Mean age at RCC diagnosis was 58.5 (±12) years-old.

Table 1
Peritoneal recurrence incidence.

	Peritoneal recurrence incidence (%)
Partial nephrectomy	0.48 (n = 22/4594)
Radical nephrectomy	1.44 (n = 48/3316)
Minimally invasive surgery	0.77 (n = 34/4402)
- Partial nephrectomy	0.69 (n = 20/2902)
- Radical nephrectomy	0.93 (n = 14/1500)
Open surgery	1.02 (n = 36/3506)
- Partial nephrectomy	0.11 (n = 2/1692)
- Radical nephrectomy	1.87 (n = 34/1816)

PREC incidence could be estimated for 70 patients from a common cohort of 7,985 patients who had surgery (partial or radical nephrectomy) for localized RCC. Missing data on surgical procedures for 75 patients.

3.1. PREC incidence

Incidence was calculated using the 3 exhaustive cohorts (UroCCR, NKI, IRCCS) totaling 7,985 nephrectomies from 1987 to 2023, with 70 PREC cases, yielding an incidence of 0.88%. PREC incidence was 0.77% and 1.02% for MIS and open surgery, 0.48% and 1.44% for PN and RN respectively (Table 1).

3.2. PREC pattern and timing

PREC was isolated in 35 cases (30%) (iPREC). Nine patients (25.7%) had solitary or ≤ 2 peritoneal nodes, 11 (31.4%) had multiple peritoneal nodes or carcinosis, 12 iPREC could not be specified (34.3%). PREC was associated with other metastatic sites in 82 cases (70%) (mPREC). Median time to PREC was 15.9 months (1-143 months), 16.2 months for iPREC, 13.5 months for mPREC. Patient demographics at diagnosis and surgical approach are described in Table 2. PN and RN were performed in 40 (34.2%) and 77 (65.8%) cases respectively. MIS (transperitoneal laparoscopy, including robot-assisted laparoscopy) was performed in 57 (48.7%) cases: 25 patients (71.4%) in iPREC group (10 robot-assisted PN) and 32 patients (39%) in mPREC group (13 and 3 robot-assisted PN and RN respectively) (Supplementary File 1).

3.3. RCC characteristics

Clear cell renal cell carcinoma (ccRCC) was predominant (77.8%), followed by high grade papillary carcinoma (pRCC) (9.4%). Surgical margins were positive (PSM) in 19 cases (16.3%), with higher rates in iPREC group (25.7%). Leibovich risk score was predominantly high (53%) (Table 2).

3.4. PREC treatment and follow-up

First-line treatment was predominantly systemic (n = 78, 66.7%) including tyrosine-kinase inhibitors (TKI), or combination of immunotherapy (IO) with IO-IO or IO-TKI. Treatment was palliative at PREC diagnosis for 8 patients (7%). Among iPREC patients, 11 underwent surgery with curative intent (mainly patients with ≤2 nodes) and 10 remained disease-free at last follow-up (median follow-up 54 months). After a mean follow-up of 50.5 months (median 39.9 months), 69 patients (59%) died from RCC: 12 in the iPREC group (34%), 57 in the mPREC group (69%).

3.5. iPREC versus mPREC

On univariable analysis, iPREC was associated with PN (odds ratio [OR] 4.1, 95% confidence interval [CI] 1.7-9.5, P = *.001*), MIS (OR 3.3, 95% CI 1.3−8.2, P = *0.007*), lower ISUP grade (OR 2.49, 95% CI 1.02−6.05,

Table 2
Patients, surgery approach and renal cell carcinoma characteristics.

Characteristic	Total (n = 117)	iPREC (n = 35; 30%)	mPREC (n = 82; 70%)	P value[a]
Age, years	58.5 (±12)	60.5 (±12.3)	57.6 (±11.8)	*0.13*
Gender, *n* (%)				*1*
- Man	94 (80.3)	28 (80)	66 (80.5)	
- Woman	23 (19.7)	7 (20)	16 (19.5)	
BMI (kg/m^2)	26.3 (±5.2)	24.9 (±4.8)	26.5 (±5.2)	*0.85*
Nephrectomy, *n* (%)				*0.001*
- Partial	40 (34.2)	20 (57)	20 (24)	
- Radical	77 (65.8)	15 (43)	62 (76)	
Surgical approach, *n* (%)				*0.007*
- Minimally invasive surgery	57 (48.7)	25 (71)	32 (39)	
- Open surgery	48 (41)	9 (26)	39 (47.5)	
- NA	12 (10.3)	1 (3)	11 (13.5)	
Histology, *n* (%)				*0.33*
- Clear cell	91 (77.8)	26 (74)	65 (79)	
- Type 1 papillary	5 (4.3)	1 (3)	4 (5)	
- Type 2 papillary	11 (9.4)	5 (14)	6 (7)	
- Chromophobe	4 (3.4)	0	4 (5)	
- Translocation	6 (5.1)	3 (9)	3 (4)	
Sarcomatoid feature, *n* (%)				*0.55*
- Yes	16 (13.7)	3 (9)	13 (16)	
- No	97 (82.9)	29 (82)	68 (83)	
- NA	4 (3.4)	3 (9)	1 (1)	
Necrosis, *n* (%)				*1*
- Yes	61 (52.2)	17 (49)	44 (54)	
- No	48 (41)	13 (37)	35 (42)	
- NA	8 (6.8)	5 (14)	3 (4)	
ISUP (grade), *n* (%)				*0.058*
- 1-2 (<3)	30 (25.7)	13 (37)	17 (21)	
- 3-4 (≥3)	81 (69.2)	19 (54)	62 (75)	
- NA	6 (5.1)	3 (9)	3 (4)	
Stage pT, *n* (%)				*0.007*
- < pT3a	45 (38.5)	20 (57)	25 (31)	
- ≥ pT3a	70 (59.8)	14 (40)	56 (68)	
- NA	2 (1.7)	1 (3)	1 (1)	
Stage pN, *n* (%)				*0.75*
- pNx/pN0	100 (85.5)	30 (85)	70 (86)	
- ≥ pN1	14 (12)	3 (9)	11 (13)	
- NA	3 (2.5)	2 (6)	1 (1)	
Positive surgical margins, *n* (%)				*0.09*
- Yes	19 (16.3)	9 (26)	10 (12)	
- No	95 (81.2)	24 (68)	71 (87)	
- NC	3 (2.5)	2 (6)	1 (1)	
Leibovich score, *n* (%)				*0.001*
- Low	21 (17.9)	11 (31.5)	10 (12)	
- Intermediate	30 (25.7)	13 (37)	17 (21)	
- High	62 (53)	10 (28.5)	52 (63)	
- NA	4 (3.4)	1 (3)	3 (4)	

BMI = body mass index; iPREC = isolated peritoneal recurrence; mPREC = peritoneal recurrence associated with other metastatic sites; NA = data not available.

Estimates were given as mean (± standard deviation) or frequency (percentage).

[a] P value: Values were calculated using Chi-2 and Fischer tests to assess the qualitative variables and Mann-Whitney test for categorical variables.

P = 0.*043*), pT1-2 stage (OR 3.2, 95% CI 1.39−7.33, P = 0.*006*), and lower Leibovich score (OR 4.6, 95% CI 1.9 −11.0, P = 0.*001*). PSM was also more frequent in iPREC (OR 2.6, 95% CI 0.97−7.3, P = 0.*058*). In multivariable analysis, only Leibovich score remained independently associated with iPREC (OR 3.3, 95% CI 1.2−8.8, P = 0.*016*) (Table 3).

At the time of PREC diagnosis, OS was significantly better for iPREC as compared to mPREC (median 56 vs. 19 months, P = 0.*007*) (Fig. 1).

Table 3
Univariable and multivariable analyses of factors associated with isolated peritoneal recurrence (iPREC) compared to peritoneal recurrence with other metastatic sites (mPREC).

Variable	Univariable OR (95% CI)	*P*-value	Multivariable OR (95% CI)	*P-value*
Partial vs. radical nephrectomy	4.1 (1.7−9.5)	0.001	1.8 (0.63−4.7)	*0.26*
Minimally invasive vs. open surgery	3.3 (1.3−8.2)	0.007	1.6 (0.56−5.0)	*0.35*
Positive vs. negative surgical margins	2.6 (0.97−7.3)	0.058	–	–
Clear cell vs. other histology subtypes	1.3 (0.5−3.3)	0.55	–	–
Nuclear grade 1−2 vs. 3−4	2.49 (1.02−6.05)	0.043	–	–
Tumor stage pT1−2 vs. pT3−4	3.2 (1.39−7.33)	0.006	–	–
Leibovich risk score (Low−intermediate vs. High)	4.6 (1.9−11.05)	0.001	3.3 (1.2−8.8)	*0.016*

CI = confidence interval; iPREC = isolated peritoneal recurrence; mPREC = peritoneal recurrence with other metastatic sites; OR = odds ratio.
Note: Only variables selected a priori were included in the multivariable analysis.

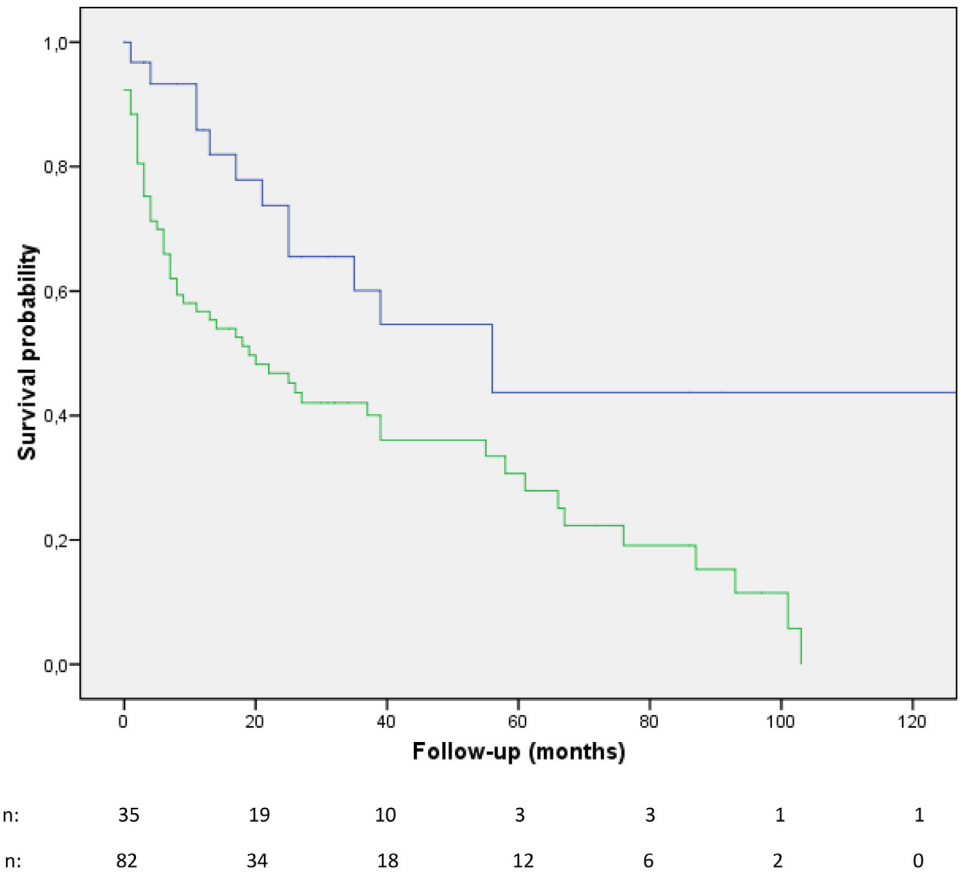

Fig. 1. Overall survival probability for patients with peritoneal recurrence (PREC) diagnosis after surgery for renal cell carcinoma: isolated PREC − iPREC (blue curve) or multiple metastatic recurrence including peritoneal site - mPREC (green curve) (*P = 0.007*).

4. Discussion

PREC is rare, with an incidence below 1% following nephrectomy for localized RCC in a median time of 15 months postsurgery.

The majority of iPREC were managed with MIS (71%), with high rate of PSM (25.7%), likely reflecting the higher proportion of PN in this group. Additionally, patients in the iPREC group predominantly had low to intermediate Leibovich risk scores. These characteristics—less aggressive tumors and more MIS and PN—contrast with those of the mPREC group, which displayed recurrence patterns more typical of advanced disease, including higher rates of open surgery, RN, and high Leibovich score. This contrast raises the hypothesis that some cases of iPREC might result from local tumor dissemination potentially related to surgical manipulation. To explore this possibility, we compared clinicopathological features between iPREC and mPREC.

Accordingly, our univariate analysis showed significant association between iPREC and PN, MIS, lower ISUP grade, pT1-T2 stage and lower Leibovich scores. These associations were no longer significant on multivariate analysis except for Leibovich risk score (OR 3.3, 95% CI, 1.2-8.8, $P = .016$). These findings support the hypothesis of 2 distinct mechanisms: 1 driven by tumor biology (mPREC), another potentially influenced by surgical factors (iPREC). However, the absence of independent associations with surgical parameters in multivariable analysis limits any definitive conclusion.

Previous studies have explored similar patterns. In the RECUR database, a higher risk of local recurrence (hazard radio [HR] 2.06) and uncommon metastases was found for MIS relative to open surgery [13]. Russo et al. [14] reported a cohort of 58 patients with atypical recurrence following MIS for RCC with insight on intraperitoneal and port site recurrences. PSM rate was relatively high (26% for pT1 tumors treated with PN), PREC was isolated in 12% of cases, and port-site recurrence occurred in 22% of cases. Mechanisms could be tumor dissemination in the peritoneum during transperitoneal laparoscopy due to insufflation or tumor manipulation, as depicted in other cancers [15]. Surgical breach of the tumor capsule (macroscopic or microscopic PSM) can also contribute to the local spillage from retroperitoneum to peritoneum during transperitoneal laparoscopy [16,17]. Robot-assisted laparoscopy addresses surgical challenges, from robot-assisted PN for complex cases (cT2, cT3, hilar tumors) to robot-assisted RN for RCC with vena cava thrombus. Time will tell if pushing the boundaries of surgical technique will lead to more atypical recurrences.

Beyond surgical factors, tumor biology remains central. In our cohort, ccRCC was predominant (77.8%), followed by high grade pRCC (9.4%). Accordingly, PREC occurrence was the highest in pRCC in other reports [6,18,19]. Furthermore, we reported higher PREC incidence for RN as compared to PN (1.44 % vs. 0.48%), with the highest incidence in open RN group, reflecting tumor complexity and advanced stage. Twenty to 40% of patients with localized RCC will eventually develop metastases irrespective of surgical management [5−7]. Tumor biology is probably the main explanation to RCC metastatic progression. The mechanisms are still unknown, the main hypothesis being hematogenous, according to the Paget's "Seed and Soil" theory, or by the lymphatic route, explaining ubiquitous metastatic patterns [5,14].

Time to PREC was relatively short (15.9 months). Accordingly, in another study, median time to atypical recurrence was 12 months [14]. Careful attention on CT scan during the first 2 years could be of interest, particularly for ccRCC, high grade pRCC, in case of PSM, or for high-risk RCC.

PREC treatment was predominantly systemic (66.7%). Interestingly, iPREC could be surgically removed in 11 cases, mainly for patients with ≤2 solitary peritoneal deposits leading to complete remission without further progression, enhancing again the potential iatrogenic or "local" cause of recurrence rather than a systemic progression. This supports the role of metastasis-directed therapy in selected patients. Lee et al. [20] showed improved outcomes after resection of solitary intra-abdominal recurrence compared to multiple metastases. Other reports also evaluated salvage treatment for local and metastatic recurrences following treatment for localized RCC [21]. Level of evidence for salvage treatment in recurrent RCC is low. Based on retrospective studies and systematic reviews that suggested survival benefits, guidelines recommend metastasectomy only if complete treatment can be performed [3,4,22−24]. In case of PREC, careful attention on CT scan evaluation would be needed, as multiple peritoneal nods may lead to uncomplete treatment with further systemic treatment. Indeed, PREC could be underdiagnosed. Apart from peritoneal carcinosis with ascites, PREC deposits can be difficult to identify at first. Diagnosis could be late or go unnoticed while several other metastatic sites are followed. For example, Win et al. incidentally discovered an omental metastasis during interaortocaval lymphadenectomy for retroperitoneal recurrence, and atypical recurrence was incidentally discovered in 83% of cases in the cohort of Russo et al. [14,25]. Most patients with PREC had poor prognosis with 7% of them being managed palliatively at PREC diagnosis and a cancer-specific mortality rate of 59% with a mean follow-up of 5 years. Stellato et al. [18] recently reported a multicenter Italian cohort study including 81 patients with PREC focusing on treatment and survival. Median overall survival was 28.3 months for metachronous metastatic RCC as compared to 21.1 months for synchronous metastatic RCC.

This study has limitations. Its retrospective design is subject to bias. Tumor breach was not systematically reported. The comparison of robotic versus laparoscopic approaches was not feasible. We lacked complete data in non-PREC cases to perform a full risk factor analysis. Furthermore, follow up was not standardized. While descriptive, we acknowledge the limitations of our study which should be taken as a source of thinking. Our study generated hypothesis for PREC occurrence and led us to develop ancillary PEMET studies to elucidate factors associated with PREC.

Despite those limitations, this is 1 of the largest European multicenter series on PREC as an atypical site of recurrence using well maintained institutional databases with information on open and minimally invasive surgery, new epidemiologic information and a long follow up.

PREC may be underestimated by urologists as the event occurs mostly in a multimetastatic context, while patients are followed up by oncologists. Since it is the only potential factor that surgeons can influence, acknowledgement of a possible link between PREC and surgery is of importance to improve our technique with the highest standards of quality. It is of utmost importance to supervise surgeons during

their first partial nephrectomies and refer complex cases to tertiary centers. Macroscopic tumor breach during surgery may occur, even in experienced hands, and must be described in operating report. In case of tumor breach or PSM, radiologists should be informed to carefully check on peritoneum during follow-up.

5. Conclusions

PREC following surgery for localized RCC is rare (<1%), often occurring within 2 years. Two patterns emerge: mPREC, likely reflecting systemic tumor spread, and iPREC, potentially influenced by surgical factors and showing better prognosis than mPREC. The hypothesis of surgical contribution in some iPREC cases, particularly after transperitoneal MIS with PSM, warrants further prospective investigation.

Ethics approval and patient consent statement

Study protocol was in accordance with the principles of the Helsinki Declaration. The study was approved by Ethic Committee (AFU-CERU_2024-038).

Declaration of competing interest

Caroline Pettenati: BMS, IPSEN, MSD, ESAI pharma. Umberto Capitanio: MSD. Laurence Albiges: AMGEN – Astellas – BMS – EISAI – Ipsen – Janssen – Merck – MSD – Novartis – Pfizer – Roche – Telix. Thibault Waeckel: I have nothing to declare. Nicolas Doumerc: Intuitive, IPSEN, MSD, BMS, Ferring, Pierre Fabre. Yann Neuzillet: IPSEN, MSD, Bristol Myers Squibb, and Eisai Pharma. Morgan Rouprêt: BMS, Pfizer Onco, IPSEN, BAYER, Provepharm, Intuitive, Astellas, Crestimogen, Photocure, Curium, Telix. Pierre Bigot: BMS, MSD, Pfizer, Ipsen. The remaining authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Caroline Pettenati: Writing – original draft, Methodology, Investigation, Data curation, Conceptualization. **Jean-Christophe Bernhard:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Data curation, Conceptualization. **Zine-Eddine Khene:** Visualization, Validation, Methodology, Formal analysis, Data curation. **Umberto Capitanio:** Writing – review & editing, Validation, Supervision, Investigation, Data curation, Conceptualization. **Giacomo Musso:** Validation, Data curation. **Laurence Albiges:** Writing – review & editing, Validation, Data curation, Conceptualization. **Larissa Rainho:** Validation, Data curation. **Gaëlle Margue:** Validation, Data curation. **Thibault Waeckel:** Validation, Data curation. **Gregory Verhoest:** Validation, Data curation. **Lucas Bento:** Validation, Data curation. **Nicolas Doumerc:** Validation, Data curation. **Louis Surlemont:** Validation, Data curation. **Yann Neuzillet:** Writing – review & editing, Supervision, Methodology, Data curation. **Thierry Lebret:** Validation, Supervision, Data curation. **Niels Graafland:** Visualization, Validation, Investigation, Data curation. **Saeed Dabestani:** Visualization, Validation, Investigation, Data curation. **Axel Bex:** Writing – review & editing, Validation, Supervision, Conceptualization. **Morgan Rouprêt:** Writing – review & editing, Validation, Supervision, Project administration, Conceptualization. **Karim Bensalah:** Writing – review & editing, Validation, Supervision, Conceptualization. **Pierre Bigot:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Formal analysis, Data curation, Conceptualization.

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Supplementary materials

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