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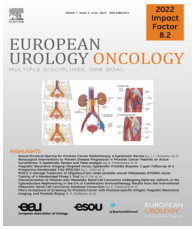

European Association of Urology

Robot-assisted Partial Nephrectomy for Hilar and Nonhilar Renal Masses: Comparison of Perioperative, Oncological, and Functional Results in a Multicentre Prospective Cohort (NEPRAH Study, UroCCR 175)

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Abstract

Background and objective: A hilar location for a renal tumour is sometimes viewed as a limiting factor for safe partial nephrectomy. Our aim was to evaluate perioperative, oncological, and functional outcomes of robot-assisted partial nephrectomy (RAPN) for hilar tumours (RAPN-H) in comparison to RAPN for nonhilar tumours (RAPN-NH).

Methods: We conducted an observational, multicentre cohort study using prospectively collected data from the French Research Network on Kidney Cancer (UroCCR). The registry includes data for 3551 patients who underwent RAPN for localised or locally advanced renal masses between 2010 and 2023 in 29 hospitals in France. We studied the impact of a hilar location on surgery, postoperative renal function, tumour characteristics, and survival. We also compared rates of trifecta achievement (warm ischaemia time [WIT]

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<25 min, negative surgical margins, and no perioperative complications) between the groups. Finally, we performed a subgroup analysis of RAPN without vascular clamping. Variables were compared in univariable analysis and using multivariable linear, logistic, and Cox proportional-hazards models adjusted for relevant patient and tumour covariates.

Key findings and limitations: The analytical population included 3451 patients, of whom 2773 underwent RAPN-NH and 678 underwent RAPN-H. Longer WIT ($\beta = 2.4$ min; $p < 0.01$), longer operative time ($\beta = 11.4$ min; $p < 0.01$) and a higher risk of postoperative complications (odds ratio 1.33; $p = 0.05$) were observed in the hilar group. Blood loss, the perioperative transfusion rate, postoperative changes in the estimated glomerular filtration rate, and trifecta achievement rates were comparable between the groups ($p > 0.05$). At mean follow-up of 31.9 mo, there was no significant difference in recurrence-free survival (hazard ratio [HR] 0.82, 95% confidence interval [CI] 0.58–1.2; $p = 0.3$), cancer-specific survival (HR 1.1, 95% CI 0.48–2.6; $p = 0.79$), or overall survival (HR 0.89, 95% CI 0.52–1.53; $p = 0.69$).

Conclusions and clinical implications: Patient and tumour characteristics rather than just hilar location should be the main determinants of the optimal surgical strategy for hilar tumours.

Patient summary: We found that kidney tumours located close to major kidney blood vessels led to a longer operation and a higher risk of complications during robot-assisted surgery to remove the tumour. However, tumours in these locations were not related to a higher risk of kidney function loss, cancer recurrence, or death.

1. Introduction

Renal cell carcinoma (RCC) is the sixth most common cancer, accounting for approximately 3% of all cancers [1]. According to the European Association of Urology guidelines, partial nephrectomy (PN) is the standard of care for management of small renal masses (T1a) and should be prioritised for localised T1b tumours [2,3]. Despite the functional advantages of PN in comparison to radical nephrectomy (RN) [4,5], the indication for PN for renal hilar masses remains controversial. For renal tumours, a location adjacent to the renal hilum is sometimes viewed as a limiting factor for safe PN because of a reportedly higher risk of perioperative complications and incomplete excision [6]. Therefore, many surgeons consider RN to be the preferred approach for hilar tumours, regardless of tumour stage.

PN can be performed via conventional open surgery or a minimally invasive (laparoscopic or robot-assisted) approach, with comparable oncological outcomes [7,8]. Robot-assisted PN (RAPN) is becoming increasingly popular for the treatment of localised kidney tumours [9] and appears to be as safe and effective as open PN for hilar tumours [10,11], with a shorter hospital stay [11].

The aim of our study was to use contemporary data prospectively collected as part of the French Network for Research on Kidney Cancer (UroCCR) project to evaluate perioperative, oncological, and functional outcomes of RAPN for hilar in comparison to nonhilar tumours.

2. Patients and methods

NEPRAH is an observational, multicentre cohort study involving analysis of prospectively collected data from the UroCCR project (NCT03293563). The study has institutional review board approval (CNIL authorisation no. DR-2013-206) and authorisation and ethical approval from the Sud-Ouest et Outre-mer III Ethics Committee (DC 2012/108) and the French Advisory Committee on Information Processing in Research in the Field of Health. All patients received oral and written information about the objectives and methodology of the UroCCR project and provided written consent.

2.1. Participants and procedures

A total of 29 hospitals in France participated in the project and 3551 patients underwent RAPN for a renal mass between 2010 and 2023. From this database, we only included patients who underwent RAPN for a localised or locally advanced renal mass. Patients with bilateral and/or multiple unilateral tumours were excluded. The surgical approach was chosen at the surgeon's discretion. All RAPN procedures were performed by experienced surgical teams using a da Vinci Si or Xi robotic platform (Intuitive Surgical, Sunnyvale, CA, USA). In some cases in which the hilar tumour had a restricted contact surface area (CSA) with the renal parenchyma, tumour excision was performed without vessel clamping [12]. The main surgical steps for "clampless" RAPN were landmark identification of the main renal artery to allow clamping at any time in case of uncontrolled bleeding, and of the main branches surrounding the tumour. Vessel loops were positioned to help the dissection between these vessels and the tumour. Suturing was not always necessary but was considered in cases of bleeding or urinary tract violation.

2.2. Data collection

Preoperative data included blood creatinine, estimated glomerular filtration rate (eGFR) calculated using the Modification of Diet in Renal Disease formula, tumour diameter,

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Table 1 – Demographic and preoperative data for patients who underwent robot-assisted partial nephrectomy stratified by location (hilar vs nonhilar) of the renal mass

	All patients (n = 3451)	Hilar (n = 678)	Nonhilar (n = 2773)	p value [a]
Median age, yr (IQR)	63 (53–70)	62 (51–71)	63 (53–70)	0.39
Sex, n (%)				0.5
Male	2298 (66.6)	444 (65.5)	1854 (66.9)	
Female	1153 (33.4)	234 (34.5)	919 (33.1)	
Right-sided tumour, n (%)	1714 (49.9)	314 (46.4)	1400 (50.7)	**0.04**
Median tumour, cm (IQR)	3.2 (2.2–4.5)	4 (3–5.5)	3 (2.2–4.4)	**<0.01**
Median PADUA score (IQR)	8 (7–10)	10 (9–11)	8 (7–9)	**<0.01**
Median RENAL score (IQR)	7 (6–9)	9 (8–10)	7 (5–8)	**<0.01**
Median preoperative creatinine, µmol/l (IQR)	79 (66–93)	79.6 (67–96)	79 (66–93)	0.28
Median preoperative eGFR, ml/min/1.73 m^2 (IQR)	86.8 (71.1–99.9)	84.4 (69.6–99.6)	85.4 (70.3–100.2)	0.35
Tumour T stage, n (%)				**<0.01**
T1a	1787 (63.4)	266 (48.4)	1521 (67.0)	
T1b	575 (20.4)	134 (24.4)	441 (19.4)	
T2a	60 (2.1)	18 (3.3)	42 (1.9)	
T2b	15 (0.5)	2 (0.4)	13 (0.6)	
T3a	356 (12.6)	125 (22.8)	231 (10.2)	
T3b	3 (0.1)	1 (0.2)	2 (0.1)	
T3c	1 (0.04)	0	1 (0.05)	
T4	2 (0.08)	1 (0.2)	1 (0.05)	
Tx	20	2 (0.4)	18 (0.8)	
ASA physical status score, n (%)	3338			0.26
ASA 1	709 (21.2)	137 (21.1)	572 (21.3)	
ASA 2	1960 (58.7)	364 (50.1)	1596 (59.3)	
ASA 3	652 (19.5)	144 (22.2)	508 (18.9)	
ASA 4	17 (0.5)	4 (0.6)	13 (0.5)	
ECOG performance status score, n (%)				0.27
0	2430 (82.1)	492 (82.7)	1938 (82.0)	
1	434 (14.7)	78 (13.1)	356 (15.1)	
2	81 (2.7)	22 (3.7)	59 (2.5)	
3	13 (0.5)	3 (0.5)	10 (0.4)	
4	0	0	0	
Median operative, min (IQR)	150 (116–201)	176 (125–225.5)	150 (114–195)	**<0.01**
Median warm ischaemia time, min (IQR)	17 (12–24)	20 (14–29)	17 (12–22)	**<0.01**
Median time to discharge, d (IQR)	2 (1–4)	2 (1–4)	3 (1–4)	0.14
Median blood loss, ml (IQR)	150 (50–300)	200 (100–400)	150 (50–300)	**<0.01**
Intraoperative transfusion, n (%)	68 (2)	18 (2.7)	50 (1.8)	0.16
Postoperative transfusion, n (%)	106 (3.1)	15 (2.2)	91 (3.3)	0.28
Intraoperative complications, n (%)	157 (4.6)	37 (5.5)	120 (4.3)	0.32
Bowel injury	8 (0.23)	1 (0.15)	7 (0.25)	0.61
Vascular injury	17 (0.5)	3 (0.44)	14 (0.51)	0.83
Pleural injury	6 (0.17)	2 (0.29)	4 (0.14)	0.4
Conversion to laparotomy	37 (1.1)	9 (1.3)	28 (1)	0.47
Postoperative medical complications, n (%)	382 (11.3)	101 (15.1)	281 (10.3)	**<0.01**
Acute kidney injury	36 (1.1)	11 (1.6)	25 (0.9)	0.09
Postoperative pulmonary complications	30 (0.88)	7 (1)	23 (0.83)	0.61
Postoperative ileus	21 (0.62)	4 (0.6)	17 (0.62)	0.94
UTI	61 (1.8)	15 (2.2)	46 (1.7)	0.33
Postoperative fever/sepsis (other than UTI)	80 (2.4)	25 (3.7)	55 (2)	**<0.01**
Acute urinary retention	39 (1.2)	11 (1.6)	28 (1)	0.18
Thrombophlebitis	2 (0.06)	0	2 (0.07)	0.48
Postoperative surgical complications, n (%)	198 (5.9)	48 (7.2)	150 (5.5)	0.1
Urinary fistula	33 (0.98)	13 (1.9)	20 (0.72)	**<0.01**
Perirenal haematoma	69 (2)	14 (2.1)	55 (2)	0.9
Parietal abscess	8 (0.24)	3 (0.44)	5 (0.18)	0.2
Pneumothorax	6 (0.18)	0	6 (0.22)	0.2
Renal artery thrombosis	4 (0.12)	2 (0.29)	2 (0.07)	0.12
Arteriovenous fistula	4 (0.12)	0	4 (0.15)	0.32
Pseudoaneurysm	30	4 (0.6)	26 (0.94)	0.38
Early surgical reintervention, n (%)	83 (2.5)	24 (3.6)	60 (2.2)	**0.04**
Postoperative complications, n (%)				0.54
Minor (Clavien-Dindo grades I–II)	406 (11.8)	94 (13.9)	312 (11.2)	
Major (Clavien-Dindo grade >II)	116 (3.3)	30 (4.4)	86 (3.1)	
Median change in eGFR, ml/min/1.73 m^2 (IQR)				
At discharge	−7.2 (−29.6 to 14.4)	−10.5 (−33.9 to 9.2)	−6.2 (−28.2 to 15.3)	0.16
At 1 mo	−5.4 (−15.0 to 2.4)	−6.9 (−19.0 to 1.4)	−4.9 (−14.4 to 2.9)	0.06
At 6 mo	−8.2 (−18.1 to 1.1)	−10.2 (−20.5 to −1.3)	−8.0 (−17.7 to 1.5)	0.25

IQR = interquartile range; eGFR = estimated glomerular filtration rate; ASA= American Society of Anesthesiologists; ECOG= Eastern Cooperative Oncology Group; UTI = urinary tract infection.

[a] Statistically significant p values are shown in bold font.

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tumour location (hilar tumours were defined as any suspicious renal mass in the renal hilum that was in physical contact with the renal artery and/or renal vein on preoperative computed tomography [13]), and RENAL and PADUA scores. Intraoperative data recorded included operating room time, estimated blood loss, intraoperative blood transfusions, clamping type, warm ischaemia time (WIT), and intraoperative complications. Postoperative data recorded were medical and surgical complications, length of hospital stay, blood creatinine, and eGFR at discharge and at 1 mo and 6 mo. Postoperative complications were reported according to the modified Clavien-Dindo classification [14] and stratified as minor (grade I–II) and major (grade >II) complications. Pathology specimens were evaluated by a surgical pathologist in each institution and staged according to the TNM classification [15,16]. Trifecta achievement, defined as the combination of WIT <25 min, negative surgical margins, and no perioperative complications [17], was also recorded. Finally, recurrence, cancer-specific mortality, and overall mortality on follow-up were recorded for survival analyses.

2.3. Outcomes

The primary outcomes were the impact of hilar tumour location on (1) surgical parameters, particularly bleeding, WIT, operating time, and complication rates; (2) postoperative eGFR at discharge and 1 mo and 6 mo; (3) tumour characteristics and patient survival, including histology, tumour margin status, recurrence-free survival (RFS), overall survival (OS), and cancer-specific survival (CSS). We also calculated and compared trifecta rates between the groups. Finally, we performed a subgroup analysis for patients who underwent RAPN without vascular clamping (clampless technique).

2.4. Statistical analysis

Descriptive statistics were used to explore perioperative and pathological variables. Results for continuous variables are reported as the mean and standard deviation or median and interquartile range (IQR), whereas results for categorical variables are presented as the frequency and proportion. Associations between tumour location (hilar vs nonhilar) and categorical variables were assessed using a χ^2 test or Fisher's exact test. Differences in continuous variables were analysed using Student's t test or the Mann-Whitney U test. When relevant, multivariable regression models were used to compare perioperative outcomes. For continuous outcomes, hilar and nonhilar groups were compared using multivariable linear regression models after verifying the normality of the residuals. For binary outcomes, multivariable binary logistic regression models were used after verifying an adequate sample size. In addition to tumour location (hilar vs nonhilar), variables tested in multivariable regression models were age at surgery, American Society of Anesthesiologists (ASA) physical status score, Eastern Cooperative Oncology Group (ECOG) performance status score, tumour size, and RENAL nephrometry score. Kaplan-Meier curves were generated to compare RFS, CSS, and OS between the hilar and nonhilar groups, with univariable analysis used to calculate p values. Multivariate Cox proportional-hazards analyses were performed to evaluate factors predictive of RFS, CSS, and OS. All statistical analyses were performed using RStudio v2021.09.0+351; a p value $\leq$0.05 was considered to indicate statistical significance.

3. Results

Our cohort included 3451 patients who met the inclusion criteria and underwent RAPN, of whom 2773 had a nonhilar

Table 2 – Final pathology results for renal masses treated with robot-assisted partial nephrectomy stratified by tumour location (hilar vs nonhilar)

	All patients (n = 3451)	Hilar (n = 678)	Nonhilar (n = 2773)	p value [a]
Tumour margin, n (%)				0.62
Negative	2818 (85.7)	556 (86.9)	2262 (85.4)	
Positive	202 (6.1)	37 (5.8)	165 (6.2)	
In contact	269 (8.2)	47 (7.3)	222 (8.4)	
Tumour subtype on histology, n (%)				
Clear cell RCC	1954 (58.6)	411 (63.1)	1543 (57.5)	**0.01**
Papillary RCC	464 (13.9)	55 (8.4)	409 (15.2)	**<0.01**
Chromophobe RCC	288 (8.6)	61 (9.4)	227 (8.5)	0.46
Oncocytoma	305 (9.2)	56 (8.6)	249 (9.3)	0.59
ISUP grade, n (%)				**<0.01**
Grade 1	185 (7.4)	26 (5.3)	159 (7.8)	
Grade 2	1372 (54.6)	252 (51.6)	1120 (55.3)	
Grade 3	769 (30.6)	156 (32.0)	613 (30.3)	
Grade 4	188 (7.5)	54 (11.1)	134 (6.6)	
Tumour necrosis, n (%)	489 (17.1)	112 (20)	377 (16.4)	**0.04**
Sarcomatoid features, n (%)	131 (4.6)	45 (8.1)	86 (3.7)	**<0.01**
pN stage, n (%)				**<0.01**
N0	800	120 (22.1)	680 (30.3)	
N1	10	4 (0.72)	6 (0.27)	
N2	5	1 (0.18)	4 (0.18)	
Nx	1971	419 (77)	1552 (69.2)	

RCC = renal cell carcinoma; ISUP = International Society of Urological Pathology.
[a] Statistically significant p values are shown in bold font.

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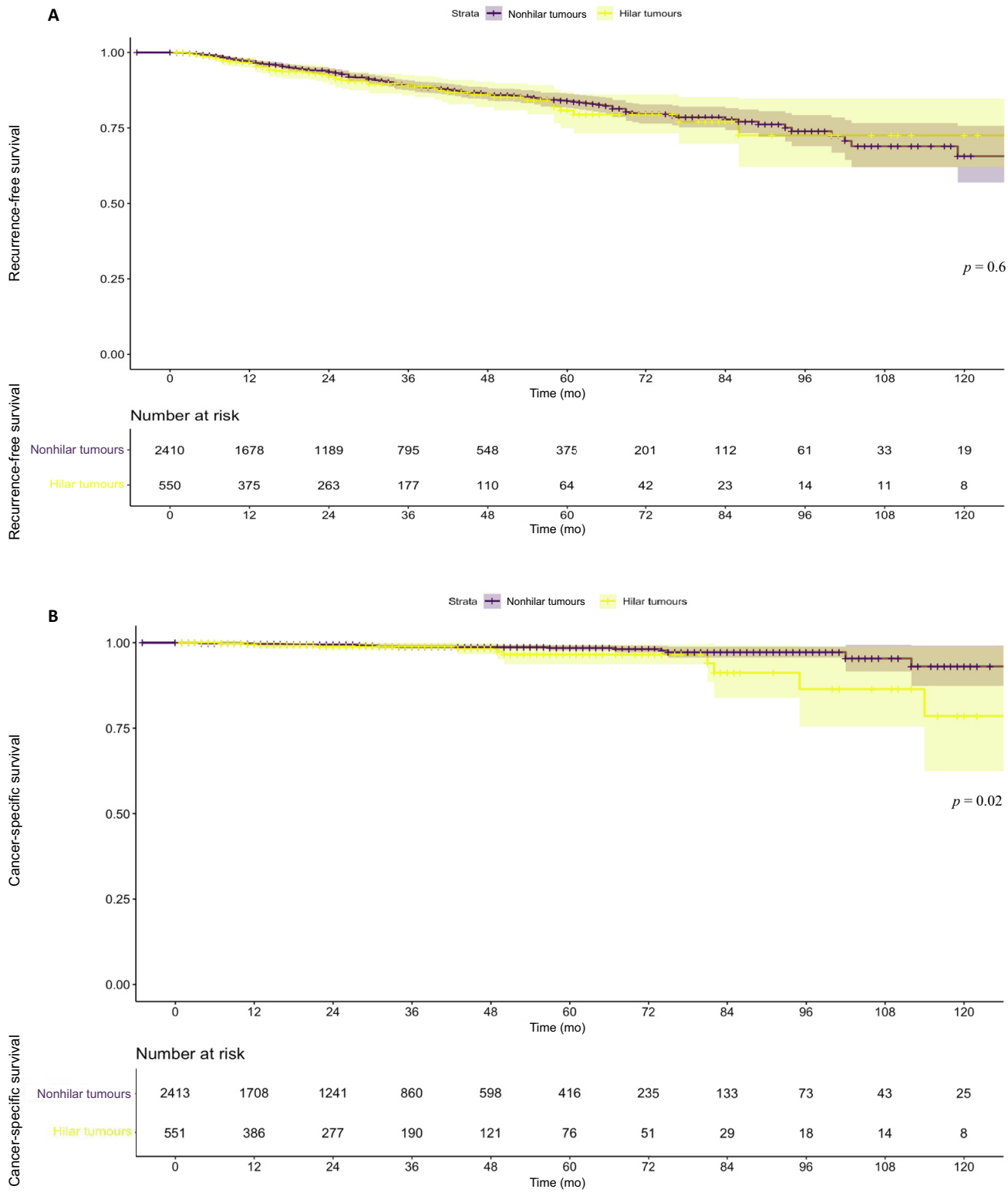

Fig. 1 – Kaplan-Meier curves of (A) recurrence-free survival, (B) cancer-specific survival, and (C) overall survival for patients treated with robot-assisted partial nephrectomy, stratified by hilar versus nonhilar location of the renal mass. $p \leq 0.05$ is considered statistically significant.

tumour and 678 had a hilar tumour. Demographic and perioperative data overall and for the two groups are summarised in Table 1.

3.1. *Surgical outcomes*

Median WIT (20 vs 17 min) and operating time (176 vs 150 min) were longer in the hilar group ($p < 0.01$) on bivariate

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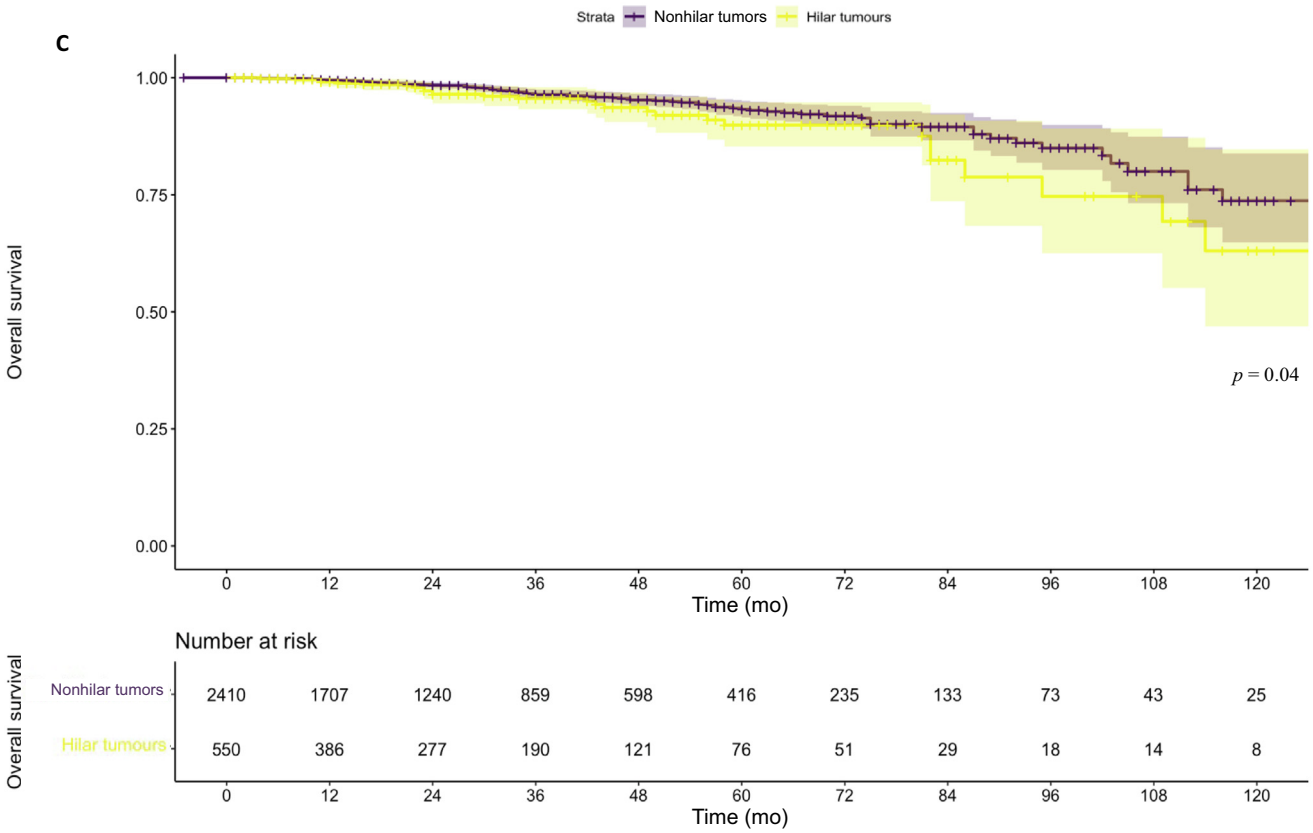

Fig. 1 (*continued*)

analysis. Blood loss was also significantly higher in the hilar group (200 ml vs 150 ml, $p < 0.01$), but the rates of intraoperative and postoperative transfusion were comparable ($p = 0.16$ and 0.28, respectively). Longer WIT ($\beta = 2.4$ min; $p < 0.01$) and longer operative time ($\beta = 11.4$ min; $p < 0.01$) were still observed in the hilar group on multivariable analysis (MVA) after adjusting for age, ASA score, ECOG score, tumour size, and RENAL score. Blood loss ($\beta = 8.1$ ml; $p = 0.59$) and rates of intraoperative transfusion (odds ratio [OR] 1.14; $p = 0.64$) and postoperative transfusion (OR 0.6; $p = 0.09$) were comparable on MVA.

The rates of intraoperative (OR 0.89; $p = 0.62$) and postoperative (OR 1.1; $p = 0.64$) surgical complications were comparable between the groups on MVA. The rate of postoperative medical complications was significantly higher in the hilar group (OR 1.33; $p = 0.05$). The risk of major complications (Clavien-Dindo grade >II) was similar between the groups on MVA (OR 1.3; $p = 0.42$).

3.2. Functional outcomes

The two groups had comparable preoperative eGFR (84.4 vs 85.4 ml/min/1.73 m^2; $p = 0.35$). On bivariate analysis, changes in eGFR at hospital discharge ($p = 0.16$) and at 1 mo ($p = 0.06$) and 6 mo ($p = 0.25$) after surgery were comparable between the groups. This was confirmed on MVA ($\beta = -3.1$ ml/min/1.73 m^2, $p = 0.68$ at discharge; $\beta = -2.35$ ml/min/1.73 m^2, $p = 0.18$ at 1 mo; $\beta = -2.3$ ml/min/1.73 m^2, $p = 0.35$ at 6 mo).

3.3. Oncological outcomes

The risk of malignancy was comparable between the groups (86.0% vs 85.8%; $p = 0.88$). The hilar group had significantly higher rates of clear cell RCC (63.1% vs 51.7%; $p = 0.01$), sarcomatoid features (8.1% vs 3.7%; $p < 0.01$), and tumour necrosis (20% vs 16.4%; $p = 0.04$), and a significantly lower rate of papillary RCC (8.4% vs 15.2%; $p < 0.01$; Table 2). The hilar group had a lower rate of International Society of Urological Pathology (ISUP) grade 1 tumours (5.3% vs 7.8%) and a higher rate of ISUP grade 4 tumours (11.1% vs 6.6%; $p < 0.01$). The positive surgical margin (PSM) rate was similar between the groups (5.8% vs 6.2%; $p = 0.62$).

Survival data were available for 2960/3451 patients (85.8%). At mean follow-up of 31.9 ± 29.2 mo (median 24 mo, IQR 10–47), 118 patients (4%) had died, of whom 35 (1.2%) died from RCC. Recurrence occurred in 275 patients (9.3%). Unadjusted Kaplan-Meier survival analysis showed a comparable risk of recurrence (hazard ratio [HR] 1.08, 95% confidence interval [CI] 0.8–1.5; $p = 0.61$; Fig. 1A) between the groups and a higher risk of cancer-specific mortality (HR 2.3, 95% CI 1.1–4.6; $p = 0.02$; Fig. 1B) and overall mortality (HR 1.6, 95% CI 1.03–2.4; $p = 0.04$; Fig. 1C) in the hilar group. After adjusting for clinicopathological covariates (Table 3),

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Table 3 – Multivariable analysis of risk factors associated with disease recurrence, death from renal cell carcinoma, and all-cause mortality following robot-assisted partial nephrectomy (*n* = 2096)

	Disease recurrence		Cancer-specific mortality		All-cause mortality	
	HR (95% CI)	*p* value	HR (95% CI)	*p* value	HR (95% CI)	*p* value
Hilar tumour	0.82 (0.58–1.2)	0.3	1.1 (0.48–2.6)	0.79	0.89 (0.52–1.53)	0.69
Age at surgery	1.01 (1–1.02)	0.03	1.02 (1–1.06)	1.1	1.06 (1.04–1.08)	<0.01
RENAL score	1.03 (0.97–1.1)	0.34	1.2 (0.94–1.4)	0.16	1.05 (0.95–1.2)	0.34
pT stage (pT2–4 vs <pT2)	2.2 (1.6–3.1)	<0.01	3.9 (1.8–8.6)	<0.01	1.9 (1.2–3.1)	<0.01
ISUP grade	1.6 (1.2–1.9)	<0.01	2.2 (1.1–4.3)	0.03	1.2 (0.9–1.7)	0.27
Sarcomatoid features	2.2 (1.4–3.6)	<0.01	2.5 (0.8–7.7)	0.11	2.6 (1.2–5.7)	0.02
Positive surgical margin	1.6 (1.1–2.4)	0.02	0.8 (0.24–2.7)	0.73	0.84 (0.38–1.)8	0.66

HR = hazard ratio; CI = confidence interval; ISUP = International Society of Urological Pathology.

there was no statistically significant difference in cancer recurrence (HR 0.82, 95% CI 0.58–1.2; $p = 0.3$), cancer-specific mortality (HR 1.1, 95% CI 0.48–2.6; $p = 0.79$), or all-cause mortality (HR 0.89, 95% CI 0.52–1.53; $p = 0.69$).

3.4. *Trifecta rates*

A trifecta outcome was achieved in 2153 patients (62.4%) in the overall RAPN cohort. Bivariate analysis revealed a significantly lower trifecta rate for the hilar group (55% vs 64.2%; $p < 0.01$). On MVA adjusted for tumour size, RENAL nephrometry score, ASA score, ECOG score, and age, hilar location was not a strong predictor of trifecta achievement (OR 0.84; $p = 0.09$). The strongest predictors for trifecta achievement were tumour size (OR 0.91; $p < 0.01$) and RENAL nephrometry score (OR 0.93; $p < 0.01$).

3.5. *Clampless RAPN subgroups*

From our initial cohort of 3451 patients, 652 (18.9%) underwent clampless RAPN, of whom 95 had a hilar tumour and 557 had a nonhilar tumour (Table 4). Median blood loss and transfusion and complication rates were comparable between the two clampless subgroups ($p > 0.5$). Regarding renal function, there was no significant difference in the change in eGFR at discharge or at 1 mo or 6 mo ($p > 0.5$). Furthermore, the PSM rate (6.5% vs 4.4%; $p = 0.62$), RFS (HR 0.87, 95% CI 0.34–2.2; $p = 0.78$), CSS (HR 1.89, 95% CI 0.53–6.7; $p = 0.32$), and OS (HR 2.4, 95% CI 0.83–6.9; $p = 0.11$) were comparable between the clampless subgroups on univariable analysis.

4. Discussion

Preoperative data revealed that hilar tumours tended to be significantly larger in size than nonhilar tumours, with a higher clinical tumour stage as a consequence. This finding has been also observed in other RAPN cohorts [18,19] and adds further anatomic complexity to hilar tumours. However, despite their delicate location, apparent larger size, and a longer operative time, the risk of intraoperative complications during RAPN was not higher for hilar than for nonhilar tumours (Table 1). In particular, the risks of vascular injury, intraoperative bleeding, and perioperative transfusion were comparable between the groups on MVA. Therefore, our findings refute claims that just the proximity of hilar tumours to major renal vessels represents a contraindication to RAPN. In a cohort of 31 patients who underwent PN for a hilar tumour, Miyake et al [10] found that blood loss was significantly lower with a robotic approach than with an open approach. This can probably be attributed to the compressive effect of pneumoperitoneum and/or the more precise vascular dissection, which makes RAPN an interesting approach to minimise bleeding in hilar surgery. Postoperative complications are another concern when treating hilar tumours. While the rate of postoperative surgical complications was similar between our hilar and nonhilar groups, the risk of postoperative medical complications was higher for the hilar group on both bivariate analysis and MVA. Despite the higher risk of postoperative medical complications, the hilar group did not have a higher risk of Clavien-Dindo grade >II complications.

RAPN for hilar tumours was associated with longer WIT. Longer WIT for hilar RAPN has been consistently observed across the literature [18–21]. However, the clinical relevance of this observation is debatable, as several studies have shown that nephron-sparing (and not WIT) is the defining factor in long-term renal function after nephron-sparing surgery [22]. Although median WIT was statistically significantly longer in the hilar group (20 vs 17 min; $p < 0.01$), this difference was clinically insignificant given that it remains below the safe cutoff of 25 min [22]. Even acknowledging the importance of WIT, our comparative analysis did not reveal any difference between the groups for the change in eGFR or the risk of acute kidney injury after surgery. In a large recent analysis of RAPN for hilar tumours, Sunaryo et al [19] found a greater percentage point decrease in eGFR at discharge in the hilar group that was only slightly worse after adjustment for tumour size and nephrometry score. These observations are similar to ours and confirm the minimal functional impact of hilar RAPN. Finally, hilar location was not associated with a lower rate of trifecta achievement on multivariable analysis, for which tumour size and RENAL nephrometry score were the strongest predictors ($p < 0.01$). The latter two factors, along with hospital volume, must be taken into consideration to maximise trifecta achievement [23].

In the proper hands, zero-ischaemia clampless RAPN is possible for hilar tumours. The safety and feasibility of clampless RAPN were initially reported for a series of seven hilar RAPN cases, with negative tumour margins in all patients [24]. Wider adoption of clampless RAPN has led to favourable perioperative data for complex tumours

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Table 4 – Demographic, surgical, functional, and oncological data for the subgroup of patients who underwent clampless robot-assisted partial nephrectomy stratified by location (hilar vs nonhilar) of the renal mass

	Clampless robot-assisted partial nephrectomy			
	Overall (n = 652)	Hilar (n = 95)	Nonhilar (n = 557)	p value [a]
Median age, yr (IQR)	63 (53–70)	64 (54–70.5)	63 (53–70)	0.47
Median tumour diameter, cm (IQR)	3 (2.1–4)	3.5 (2.9–4.7)	3 (2–4)	**<0.01**
Median RENAL score (IQR)	6 (5–8)	8 (7–10)	6 (4–7)	**<0.01**
Median preoperative creatinine, µmol/l (IQR)	79 (66.7–91.2)	73 (66–87.6)	79 (67–92.5)	0.55
Median preoperative eGFR, ml/min/1.73 m^2 (IQR)	85.4 (70.8–101.1)	87.1 (77–101.5)	85 (70.3–101.1)	0.55
Median operative time, min (IQR)	144 (105–205)	137 (99.5–200.5)	144 (105–205)	0.54
Median time to discharge, d (IQR)	1 (1–2)	1 (1–2)	1 (1–2)	0.44
Tumour T stage, n (%)				**<0.01**
T1a	383 (73.1)	41 (52.6)	342 (76.7)	
T1b	96 (18.3)	26 (33.3)	70 (15.7)	
T2a	11 (2.1)	3 (3.8)	8 (1.8)	
T2b	2 (0.4)	0	2 (0.4)	
T3a	30 (5.7)	8 (10.3)	22 (4.9)	
T3b	0	0	0	
T3c	0	0	0	
T4	0	0	0	
Tx	2 (0.4)	0	2 (0.4)	
ECOG performance status score, n (%)				0.16
0	478 (81.6)	74 (89.2)	404 (80.3)	
1	88 (15)	9 (10.8)	79 (15.7)	
2	17 (2.9)	0	17 (3.4)	
3	3 (0.5)	0	3 (0.6)	
4	0	0	0	
Median blood loss, ml (IQR)	150 (50–300)	100 (50–300)	150 (50–250)	0.95
Intraoperative transfusion, n (%)	9 (1.4)	1 (1.1)	8(1.4)	0.91
Postoperative transfusion, n (%)	9 (1.4)	2 (2.1)	7 (1.3)	0.57
Intraoperative complications, n (%)	28 (4.3)	1 (1.1)	27 (4.8)	0.09
Postoperative medical complications, n (%)	68 (10.5)	8 (8.6)	60 (10.8)	0.52
Postoperative surgical complications, n (%)	23 (3.5)	2 (2.2)	21 (3.8)	0.43
Tumour margin, n (%)				
Negative	497 (78.3)	73 (78.5)	424 (78.2)	0.62
Positive	30 (4.7)	6 (6.5)	24 (4.4)	
In contact	108 (17)	14 (15.1)	94 (17.4)	
Median change in eGFR, ml/min/1.73 m^2 (IQR)				
At discharge	−5.1 (−28.1 to 18.9)	−8.4 (−34.7 to 15.0)	−3.4 (−26.6 to 19.2)	0.40
At 1 mo	−5.9 (−14.8 to 1.4)	−7.6 (−17.8 to 0.1)	−5.1 (−13.6 to 1.6)	0.47
At 3 mo	−10.1 (−19.6 to −0.2)	−12.2 (−19.0 to −0.5)	−9.7 (−19.6 to 0.1)	0.71

ECOG = Eastern Cooperative Oncology Group; eGFR = estimated glomerular filtration rate; IQR = interquartile range.
[a] Statistically significant p values are shown in bold font.

(RENAL score >9) [25], large masses [26], and endophytic tumours [27]. We performed a subgroup comparison of clampless RAPN for 95 hilar and 557 nonhilar tumours (Table 4). To the best of our knowledge, this is one of the largest clampless RAPN cohorts for hilar tumours. We found that despite the larger tumour size and higher nephrometry scores, clampless RAPN was comparable between the hilar and nonhilar groups in terms of blood loss and transfusion and complication rates. Rates of PSM and cancer recurrence were also comparable on univariable analysis. Our results show that clampless RAPN for hilar tumours is not associated with a higher risk of complications or incomplete resection. In our opinion, this highlights the importance of CSA in clampless RAPN. CSA is a measure of the tumour surface area contiguous with benign parenchyma, and it has been shown that CSA rather than tumour size and complexity is associated with complications [28]. CSA, rather than hilar location of a renal mass, predetermines the safety and feasibility of clampless RAPN.

We also assessed the histopathological characteristics of hilar tumours. We found that 86% of hilar renal masses in our cohort were malignant, which was comparable to the rate for nonhilar renal masses. Similarly, in an extensive histopathological review of 1324 clinical stage 1 hilar masses, Correa et al [29] did not find differences in the risk of malignancy or upstaging in comparison to nonhilar tumours. However, our subtype analysis revealed that hilar tumours were more aggressive, with significantly higher risks of clear cell RCC ($p = 0.01$), sarcomatoid features ($p < 0.01$), ISUP grade 4 ($p < 0.01$), and tumour necrosis ($p = 0.04$). Similar findings, especially a higher risk of clear cell RCC, have been reported for other cohorts of patients with hilar renal tumours [30–32], suggesting that the natural history and tumour evolution differ between hilar and nonhilar masses. Nonetheless, aggressive histological subtypes and features should not be considered as contraindications to PN. Complete oncological excision can be achieved with RAPN regardless of tumour location. In our

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cohort, the PSM rate on final pathology was similar between the hilar and nonhilar groups ($p = 0.62$). Hilar location was not associated with a higher risk of recurrence, cancer-specific mortality, or overall mortality on MVA. Age, pathological stage ≥pT2, high-grade disease, sarcomatoid features, and PSM status were the main factors associated with recurrence. They were also (except for PSM) associated with cancer and/or overall mortality. Patient and tumour characteristics are therefore better determinants of oncological outcomes after RAPN than tumour location (hilar vs nonhilar).

Our study is limited by its retrospective design and a risk of selection bias because of unmeasured variables. The multicentre design may be a source of information bias, as data can be coded differently from one centre to another. Second, our median follow-up of 24 mo (IQR 10–47) may be short in comparison to other cohorts [29] and in relation to the risk of late recurrences in renal cell carcinoma. It is therefore complicated to draw definitive conclusions regarding oncological outcomes. Finally, we used RENAL and PADUA nephrometry scores in our study to assess the complexity of renal masses. While these scoring systems are widely used in clinical practice, they do not offer a specific scoring component tailored to hilar tumours. The more recent RPN nephrometry score [33] offers a mechanism for scoring hilar tumours and would offer a more nuanced and logical approach to assessing the complexity of hilar masses.

5. Conclusions

Hilar masses represent a separate renal tumour entity, with a larger size on surgery and aggressive subtypes and features on pathology. RAPN is a safe option for hilar tumours, with perioperative, functional, and oncological outcomes comparable to those for nonhilar tumours. Patient and tumour characteristics, rather than just tumour location, should be the main determinants of the optimal surgical strategy for hilar tumours.

Author contributions: Julien Sarkis had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Sarkis, Ingels.
Acquisition of data: Champy, Doumerc, Bruyere, Rouprêt, Branger, Surlemont, Michel, Waeckel, Parier, Beauval, Bigot, Lang, Vallee, Guillotreau, Patard, Sarrazin, de Vergie, Belas, Boissier, Mallet, Panthier, Taha, Le Clerc, Hoquetis, Audenet, Vignot, Paparel, Fontenil, Bernhard.
Analysis and interpretation of data: Sarkis, Ingels.
Drafting of the manuscript: Sarkis, Ingels, Champy.
Critical revision of the manuscript for important intellectual content: Sarkis, Ingels.
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