
Long-term Oncological and Functional Outcomes after Laparoscopic Partial Nephrectomy with Hyperselective Embolization of Tumor Vessels in a Hybrid Operating Room

[Ulysse Frantz](#)*, Antoine Bouvier, Thibaut Culty, Merzouka Zidane, Souhil Lebdai, [Pierre Bigot](#)

Posted Date: 18 July 2023

doi: 10.20944/preprints202307.1170.v1

Keywords: Hybrid operating room; Kidney cancer; Laparoscopy; Oncology; Surgery



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Article

Long-Term Oncological and Functional Outcomes after Laparoscopic Partial Nephrectomy with Hyperselective Embolization of Tumor Vessels in a Hybrid Operating Room

Ulysse Frantz ^{1,*}, Antoine Bouvier ², Thibaut Culty ³, Merzouka Zidane ⁴, Souhil Lebdaï ⁵ and Pierre Bigot ⁶

¹ Department of Urology, Angers University Hospital, France; ulyse.frantz@chu-angers.com.

² Department of Radiology, Angers University Hospital, France; AnBouvier@chu-angers.fr

³ Department of Urology, Angers University Hospital, France; ThCulty@chu-angers.fr

⁴ Department of Pathological Anatomy and Cytology, Angers University Hospital, France; MMZidame@chu-angers.fr

⁵ Department of Urology, Angers University Hospital, France; SoLebdaï@chu-angers.fr

⁶ Department of Urology, Angers University Hospital, France; PiBigot@chu-angers.fr

* Correspondence: ulyse.frantz@chu-angers.com; Tel +33 689136838.

Abstract: Laparoscopic partial nephrectomy (LPN) after hyperselective embolization of tumor vessels (HETV) in a hybrid operating room (HOR) that combines traditional surgical equipment with advanced imaging technology, is a non-clamping surgical approach to treat localized kidney tumors that have shown promising short-term results. The aim of this study was to evaluate the long-term oncological and functional outcomes of this procedure. All consecutive patients treated for a localized kidney tumor by LPN after HETV between May 2015 and October 2022 in a single academic institution were included in the study. Clinical, pathological and biological data were collected prospectively in the uroCCR database. We evaluated perioperative data, postoperative complications, surgical margin and modification of renal function after surgery. We included 245 patients. Median tumor size was 3.2 (2.5-4.4) cm. The R.E.N.A.L. complexity was low, medium and high for 104 (43.5%), 109 (45.6%) and 26 (10.9%) patients, respectively. Median LPN time was 75 (65 -100) min and median blood loss was 100 (50-300) mL. Surgical postoperative complications occurred in 56 (22.9%) patients with 17 (5.7%) major complications. The median preoperative Glomerular Function Rate (GFR) was 90.5 (77-101.8) mL/min and the median GFR variation at 6 months was -7.5 (-15- -2) mL/min. Malignant tumors were present in 211 (86.1%) patients and 12 (4.9%) patients had positive surgical margins. After a median follow-up of 27 (8-49) months, 20 (8.2%) patients had a tumor recurrence and 4 (1.6%) died from cancer. The use of a HOR to perform LPN after HETV is a safe and efficient non-clamping approach to treat localized kidney tumors.

Keywords: hybrid operating room; kidney cancer; laparoscopy; oncology; surgery

1. Introduction

Kidney cancer is one of the most common types of cancer with an estimated 138,600 new cases and 54,000 deaths in Europe in 2020 [1]. International guidelines consider partial nephrectomy (PN) as the gold standard technique for localized kidney tumors treatment [2,3]. Different approaches are described such as open partial nephrectomy (OPN), laparoscopic partial nephrectomy (LPN), or robot-assisted laparoscopic partial nephrectomy (RALPN). Compared to OPN, and to LPN: RALPN provides decreased intraoperative blood loss, shorter hospitalization time, fewer complications, and shorter ischemia times [4,5]. As a result, RALPN has become the new gold standard technique for mini-invasive PN [6]. LPN can be complex, with a prolonged learning curve, due to limited ergonomics and to technical challenges such as laparoscopic suture [7]. Simone and al. have described a zero-ischemia technique of PN after selective embolization of tumor vessels. The main disadvantages of their technic were prolonged delays between the embolization step and the surgical

step (up to 24 hours), resulting in peri-lesioned edema increasing the tumor dissection difficulty [8,9]. Next-generation hybrid operating rooms combine traditional surgical equipment with advanced imaging technology and allow both procedures to be performed together while optimizing the time between the embolization and the surgical steps [10]. LPN after hyperselective embolization of tumor vessels (HETV) in a hybrid operating room (HOR) is a non-clamping approach which has been performed in our center since 2015 [11]. The first short-term results were encouraging regarding operative times, bleeding, postoperative renal function, and the risk of arterial pseudoaneurysm [12–14]. The aim of this study was to evaluate the long-term oncological and functional results of LPN after HETV in HOR for localized kidney tumors.

2. Materials and Methods

2.1. Patients

We included all the patients treated for a localized kidney tumor by LPN after HETV in a HOR between May 2015 and October 2022 in our academic institution. Clinical, pathological, and biological data were collected prospectively, after informed consent, in the uroCCR database (NCT03293563, CNIL authorization number: DR-2013-206). Patient demographics studied were age, gender, BMI, solitary kidney, and ASA score. The indication of partial nephrectomy was imperative if patients had bilateral tumors, solitary kidney, or chronic kidney disease (eGFR according to CKD-EPI < 60 mL/min/1.73m²). CKD-EPI was used to assess pre and postoperative renal functions. Tumor characteristics were side and size, histology, T stage, and ISUP grade [15]. R.E.N.A.L. score was used to classify lesions into low (4-6), medium (7-9), and high (≥ 10) surgical complexity [16].

2.2. Perioperative and Postoperative Outcomes

We evaluated the complete operating time (embolization plus laparoscopy) and the laparoscopic time alone, blood loss, the number of arterial branches embolized, perioperative complications, and transfusions. We rated postoperative complications, according to the Clavien-Dindo classification [17]. Major postoperative complications were defined as Clavien score > 2 . We analyzed the length of hospital stay, surgical margins, and oncological recurrences. The need for complementary local intervention such as new partial nephrectomy, radical nephrectomy, or radiofrequency was assessed in patients with malignant pathology.

2.3. Angiographic and Surgical Procedure

All procedures were performed under general anesthesia in a Discovery IGS 730 (GE Healthcare) operating room by different urological surgeons (n=15) and interventional radiologists (n=3) as described previously [11]. Intra-arterial injection of blue dye during tumor embolization was performed in order to facilitate tumor localization [11,18]. (Figure 1).

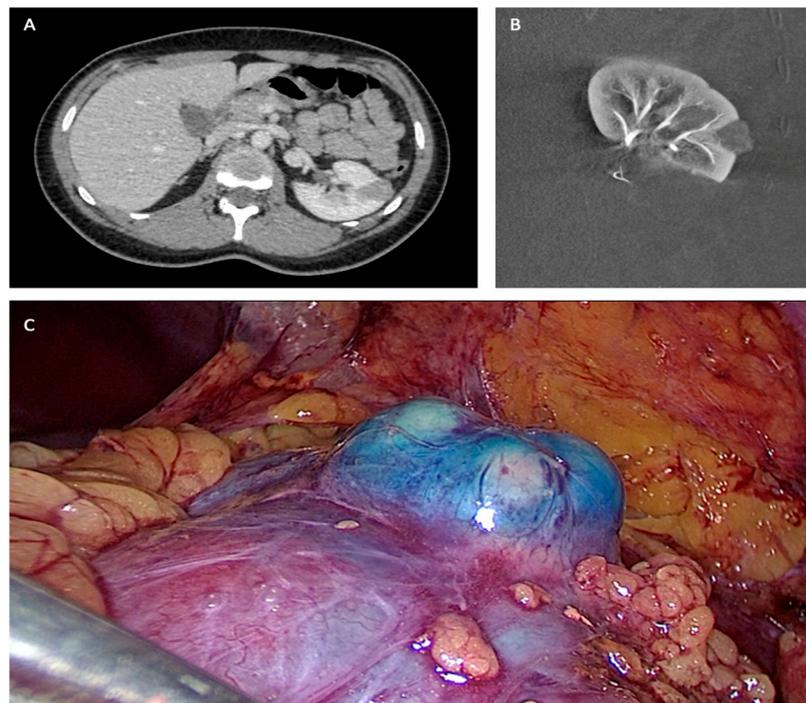


Figure 1. (A) Pre-operative TDM (B) Post embolization angiography (C) Per-operative laparoscopic view.

2.4. Follow-up

Patients had postoperative visits at one month and six months. In case of malignant tumor, follow-up rhythm was defined according to the French oncology recommendation guidelines [2]. Surveillance was done using CT-scan, physical and biological analysis.

2.5. Statistical Analysis

Disease-free survival, specific survival, and overall survival were calculated based on the Kaplan-Meier method. Recurrence risk factors were evaluated in patients with malignant pathology using a Cox regression analysis. We analyzed complication risk factors by doing univariate analysis and multivariate analysis. The significance threshold p was set at 0.05.

Qualitative variables were described with absolute values and percentages, and quantitative values with median, first quartile, and third quartile. Statistical analyses were performed with SPSS® Version 15.0 Software.

3. Results

3.1. Patient and Tumor Characteristics

Between May 2015 and October 2022, 245 patients were included in the study. There were 163 (66.5%) males and 82 (33.5%) females. The median age was 64 (52-72) years. The operative indication was elective for 215 (87.8%) patients and imperative for 30 (12.2%) patients. The median tumor size was 3.2 (2.5-4.4) cm. The R.E.N.A.L. complexity was low, moderate, and high for respectively 104 (43.5%), 109 (45.6%), and 26 (10.9%) patients. Patient and tumor characteristics are reported in Table 1.

Table 1. Patients and tumors characteristics.

Laparoscopic Partial Nephrectomy After Selective Embolization of Tumor Vessels (n = 245)	
Median age, years [IQR]	64 [52 - 72]
Gender, n (%)	
Male	163 (66.5)
Female	82 (33.5)
Median BMI, kg/m ² [IQR]	27.3 [24.5 - 30.8]
Solitary kidney, n (%)	2 (0.8)
ASA score, n (%)	
ASA 1	43 (17.6)
ASA 2	145 (59.4)
ASA 3	55 (22.5)
ASA 4	1 (0.5)
Side, n (%)	
Right	127 (51.8)
Left	118 (48.2)
Median tumor size, cm [IQR]	3.2 [2.5 - 4.4]
R.E.N.A.L. complexity, n (%)	
Low	104 (43.5)
Moderate	109 (45.6)
High	26 (10.9)
Indication, n (%)	
Elective	215 (87.8)
Imperative	30 (12.2)
Median preoperative eGFR CKD-EPI, mL/min/1.73m ² [IQR]	90.5 [77 - 101.8]
Median follow-up, month [IQR]	27 [8 - 49]
BMI = Body Mass Index; IQR = Inter-Quartile Range; eGFR = estimated Glomerular Filtration Rate	

3.2. Operative Outcomes

Median total operative and laparoscopic times were respectively 168 (145-199) min and 75 (60-100) min. The number of arterial branches embolized was 1, 2, 3, 4, and 5 for 88 (36.1%), 99 (40.6%), 41 (16.8%), 15 (6.1%), and 1 (0.4%) patients, respectively. Median blood loss was 100 (50-300) mL. There were 10 perioperative complications (4.1%): 5 hemorrhages with transfusion required in 4 (1.6%) patients, 2 vascular wounds that have been clipped, 1 splenic wound that has been coagulated, 1 ureteral wound that required perioperative suture and a JJ catheter and one open conversion for tumor localization difficulties. Perioperative data are reported in Table 2.

Table 2. Perioperative and postoperative characteristics.

Laparoscopic Partial Nephrectomy After Selective Embolization of Tumor Vessels (n = 245)	
Median total operative time, min [IQR]	168 [145 - 199]
Median laparoscopic time, min [IQR]	75 [60 - 100]
Median blood loss, mL [IQR]	100 [50 - 300]
Number of arterial branches embolized, n (%)	
1	88 (36.1)
2	99 (40.6)
3	41 (16.8)
4	15 (6.1)
5	1 (0.4)

Perioperative complications, n (%)	10 (4.1)
Perioperative transfusions, n (%)	4 (1.6)
Postoperative complications CLAVIEN, n (%)	
I	32 (13.1)
II	7 (2.9)
IIIa	3 (1.2)
IIIb	12 (4.9)
IVa	1 (0.4)
V	1 (0.4)
Median hospital stay, days [IQR]	4 [3 - 4]

IQR: Inter-Quartile Range

3.3. Postoperative Outcomes

The median hospital stay was 4 (3-4) days. A total of 56 postoperative complications occurred with 39 (16%) minor and 17 (6.9%) major complications. Post-operative outcomes are reported in Table 2. We did not identify predictive factor of major postoperative complication (Table 3).

Table 3. Post-operative complications according to the Clavien Dindo Classification.

	All tumors (n=245)	Low complexity group ¹ (n=104)	Moderate Complexity group ² (n=109)	High Complexity group ³ (n=26)	p Value
All complications, n (%)	56 (22.9)	24 (23)	23 (21)	7 (26)	0.8
Major complications (Clavien > 2), n(%)	17 (6.9)	4 (3.8)	7 (6.4)	4 (15)	0.095

¹ Renal Score 4-6: Low complexity
² Renal Score 7-9: Moderate complexity
³ Renal Score 10-12: High complexity

3.4. Oncological Outcomes

There were 211 (86.1%) malignant tumors and 34 (13.9%) benign tumors. For malignant tumors pT stage was 1a, 1b, 2a, 2b, 3a in 142 (67.3%), 42 (19.9%), 9 (4.3%), 1 (0.5%), and 17 (8.1%) patients, respectively. Surgical margins were positive in 12 (4.9%) patients. There were 20 (9.5%) tumor recurrences with 17 (8.1%) local recurrences and 7 (3.3%) metastatic progressions. Local recurrences were treated by radical nephrectomy in 8 (3.8%) patients, radiofrequency ablation in 6 (2.8%) patients, intraperitoneal nodule excision in 2 (1%) patients, and by a new partial nephrectomy in 1 (0.5%) patient. During a median follow-up of 27 (8-49) months, 14 (5.7%) patients died with 4 (1.6%) specific deaths. Oncological outcomes are reported in Table 4.

Table 4. Oncological outcomes.

	Laparoscopic Partial Nephrectomy After Selective Embolization of Tumor Vessels (n = 245)
Histology, n (%)	
Benign	34 (13.9)
Angiomyolipoma	5 (2)
Renal cyst	5 (2)
Oncocytoma	22 (9)
Hemangioma	1 (0.4)
Metanephric adenoma	1 (0.4)
Malignant	211 (86.1)
Clear cell renal cell carcinoma	158 (64.5)
Collecting duct / Bellini duct carcinoma	1 (0.4)
Chromophobe renal cell carcinoma	16 (6.5)

Papillary renal cell carcinoma	34 (13.9)
Eosinophilic renal cell carcinoma	1 (0.4)
Pulmonary metastasis	1 (0.4)
<hr/>	
pT stage, n (%)	
pT1a	142 (67.3)
pT1b	42 (19.9)
pT2a	9 (4.3)
pT2b	1 (0.5)
pT3a	17 (8.1)
<hr/>	
ISUP grade, n (%)	
1	22 (10.5)
2	125 (59.2)
3	40 (19)
4	6 (2.8)
NA	18 (8.5)
<hr/>	
Surgical margins, n (%)	
Negative	233 (95.1)
Positive	12 (4.9)
<hr/>	
Recurrences, n (%)	
All recurrences	20 (9.5)
Local recurrences	17 (8.1)
Metastatic progression	7 (3.3)
<hr/>	
Surgical reoperation, n (%)	17 (8.1)
Totalisation	8 (3.8)
Partial nephrectomy	1 (0.5)
Radiofrequency ablation	6 (2.8)
Extra peritoneal nodule excision	2 (1)
<hr/>	
Deaths, n (%)	14 (5.7)
<hr/>	
Specific deaths, n (%)	4 (1.6)
<hr/>	

In multivariable analysis T stage (HR:4.4, $p=0.027$) and surgical margins (HR:4.29, $p=0.029$) were identified as recurrence risk factors (Table 5).

Table 5. Risk factor of recurrences.

	Hazard Ratio (CI 95%)	<i>p</i> Value
Age, (continuous)	1.02 (0.977 ; 1.07)	0.340
Tumor size, (continuous)	1.15 (0.843 ; 1.55)	0.386
Indication NSS		
Elective	Reference	—
Imperative	1.00 (0.289 ; 3.47)	0.997
Histology		
Other	Reference	—
Clear cell renal cell carcinoma	1.77 (0.496 ; 6.33)	0.378
ISUP grade		
1 / 2	Reference	—
3 / 4	1.71 (0.618 ; 4.75)	0.300
T Stade		
T1 & T2	Reference	—
≥ T3	4.04 (1.18 ; 13.91)	0.027
Surgical margins		
Negative	Reference	—
Positive	4.29 (1.17 ; 15.82)	0.029

 Multivariate analysis with Cox-proportion hazard regression

Disease free survival, specific survival and overall survival curves of the 211 patients with malignant pathology are shown in Figure 2.

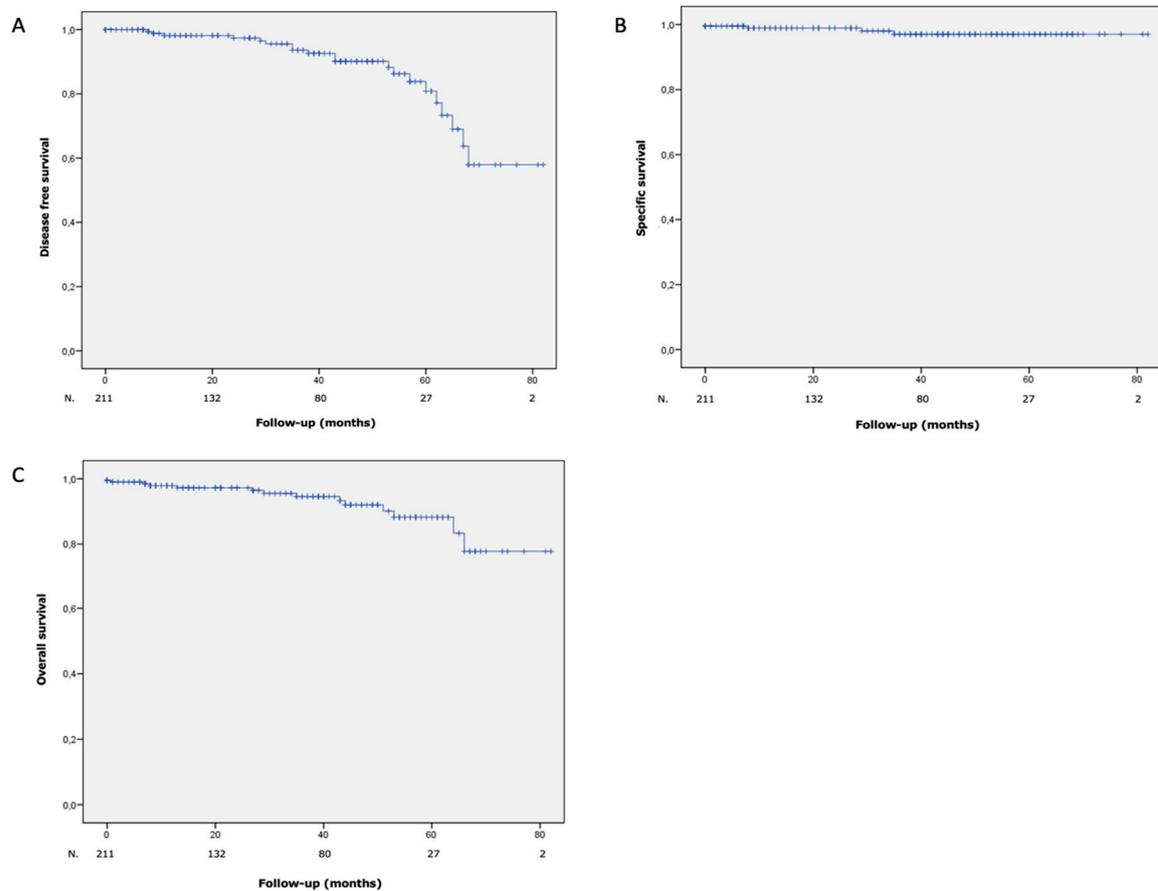


Figure 2. (A) Disease free survival, (B) Specific survival and (C) Overall survival after laparoscopic partial nephrectomy with hyperselective embolization of tumor vessels in a hybrid operating room for 211 malignant renal tumors.

3.5. Functional Outcomes

The median preoperative eGFR (CKD-EPI) was 90.5 (77-101.8) mL/min/1.73m². The median eGFR (CKD-EPI) at one month and six months were 82 (67.3-93.8) mL/min/1.73m² and 82 (66-95) mL/min/1.73m² respectively. Evolution of renal function is described in Figure 3.

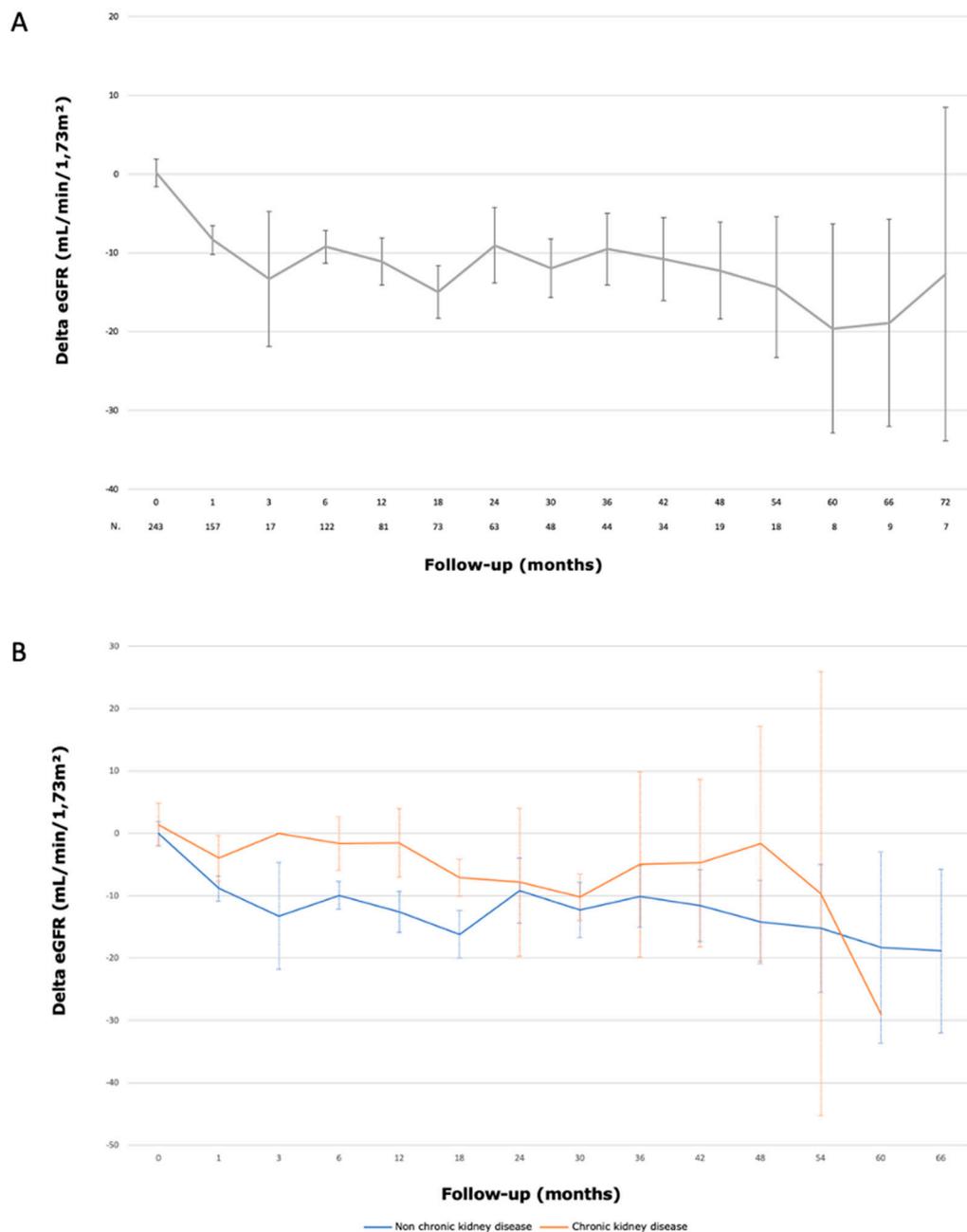


Figure 3. Evolution of renal function (eGFR) after laparoscopic partial nephrectomy with hyperselective embolization of tumor vessels in a hybrid operating room for (A) 243 localized renal tumors and (B) according to pre-existent chronic kidney disease (eGFR <60ml/min).

4. Discussion

In this study, we reported a series of LPN with HETV in HOR with a median follow-up of 27 months. The demographic data of our study were similar to those already published, in terms of age, BMI, ASA scores, tumor size, and RENAL complexity [4–6,19].

The median total operative time of 168 min, including HETV, patient repositioning, and LPN, appears to be shorter compared to other LPN series [6,20]. Our operative times seem similar to those described in the RALPN series [4,5]. The median laparoscopic time alone was reduced to 75 minutes. This could be explained by the absence of renal pedicle dissection and the possibility of suturless PN in most of the cases [5]. In addition, blue dye embolization facilitated macroscopic tumor localization

without the use of intra-body ultrasound [18]. In our study, only one (0.4%) laparo-conversion was necessary due to the difficulty in tumor localization. Simmons et al. described 6 (1%) cases of conversion [21], while Masson-Lecomte et al. had 7 (3.18%) conversions in the robot-assisted laparoscopy group and 5 (11.1%) in the laparoscopy group [22]. Dissection was always possible without difficulty related to perilesional edema, a limiting factor described when embolization was performed remotely from the surgical procedure [9].

Perioperative bleeding is the most important and severe complication of PN. In contemporary RALPN series bleeding occurred in 6% of the cases [4,5,23]. Despite the off-clamp PN, perioperative bleeding was 100 ml which is lower than bleeding reported in RALPN (150 to 300 ml) [4,5,23]. Hemostasis was achieved using hemostatic agents and in the majority of the cases did not require cortical suturing which could contribute to the preservation of healthy renal parenchyma [24]. Furthermore, only 5 (2.1%) major hemorrhages occurred, and 4 of them required perioperative blood transfusions. These results are lower than those reported in the literature [4,6,20]. The low rate of perioperative hemorrhagic complications, preventing organ hypoperfusion, could also contribute to nephron preservation. However, we did have 3 (1.2%) postoperative renal bleeding and one (0.4%) hepatic bleeding episodes, which required additional postoperative embolization. For one patient the bleeding occurred because of an embolization failure. For two others patients, bleeding occurred because of a large tumor excision with non-embolized healthy renal parenchyma removal. Simone et al. described two cases (1%) of secondary bleeding requiring additional embolization in their series of LPN after HETV [8]. However, these complications remain lower than those reported by George et al. who performed 16 (5.54%) embolizations for postoperative bleeding [25]. The use of glue for embolization appears to be a safe and effective technique [14].

Major postoperative complications were noted in 17 patients, which is consistent with the literature [6]. One patient died postoperatively from cardiac arrest secondary to uncontrolled asthma and had a history of multiple cardiovascular comorbidities (high blood pressure, aortic valve disease with mechanical cardiac valve). Minor complications were mostly isolated postoperative hyperthermia, related to a post-embolization syndrome [13].

Hospitalization times were similar to those reported in RALPN trials [19].

The deterioration of renal function after PN is a multifactorial and complex process related to non-modifiable factors (age, comorbidities, preoperative kidney function) and modifiable factors (duration of ischemia, nephron sacrifice) [7]. Mir et al. described a preservation of approximately 90% of renal function after PN [26].

In a previous study, we evaluated renal function by GFR and computed tomography renal volume 6 months after surgery in 137 patients. We found a 9.3 ml/min decreased in GFR and a median loss of 21 ml of healthy parenchyma on the operated kidney which is consistent with the literature on robot-assisted surgery [27]. With a larger population and a longer follow-up, we found a 10% loss of renal function, which remained stable over time.

Preoperative embolization of tumor arteries has several advantages: 1) the reduction of intraoperative bleeding; 2) the selective dissection of the tumor using the blue coloration of the tumor optimizing the differentiation from the normal parenchyma, and therefore a better preservation; 3) performing PN without clamping which avoids the risk of renal ischemia lasting more than 25 to 30 minutes [28]. This is an important point especially for patients suffering from preoperative chronic renal disease: HETV limited the loss of renal function to 9% at 42 months. These results should be interpreted with caution, as our population of chronic renal insufficiency patients was only 30 patients and only 4 patients were still followed-up at 42 months. Nevertheless, studies specifically focusing on this population would be interesting.

Out of the 245 patients in our series, 34 (13.9%) had benign tumors. These results are consistent with the literature. Simone et al. found 30% benign tumors, Masson-Lecomte et al. had 16% in the robot-assisted series, and Peyronnet et al. had 14.6% [4,8,21,22]. Of these 34 benign tumors, 22 were oncocytomas. However, the diagnosis is difficult, and it can be tricky to identify chromophobe renal cell carcinoma, with 9 to 25% of patients having a final diagnosis of clear cell carcinoma [29,30]. The

other benign tumors were 5 angiomyolipomas, 5 symptomatic cysts, 1 hemangioma, and a metanephric adenoma.

We identified two risk factors for recurrence: positive surgical margins and pathological stage \geq pT3a. The rate of positive margins was 4.9%. These results are similar to the robot-assisted series of Ingels et al. (4.9%), Peyronnet et al. (5.2%), Pignot et al. (5.7%) and Masson-Lecomte et al. (8%) [4,5,19,22]. However, we found a slightly higher rate (9.5%) of cancer recurrence. In their series of LPN after HETV, Simone et al. reported only two (1%) recurrences. This difference is unexpected given the similar rates of positive surgical margins. It is probably related to the aggressiveness and complexity of the tumors treated in our series. Indeed, 8.1% of our patients had a pT3a tumor with invasion of the peri-renal fat, presenting a higher risk of recurrence and Simone et al. series had only 3.3% pT3a [8]. Similarly, Peyronnet et al. reported a recurrence rate of 2.2% in their robot-assisted series, with 10.6% of pT3a stage. However, the median follow-up period was only 13 months [4]. This difference in follow-up duration may explain these differences in terms of recurrence. Masson-Lecomte et al. found a recurrence rate of 1.8% in their series with a median follow-up of 7 months and 3% of pT3a tumors [22].

All studies comparing RALPN to OPN or LPN have found benefits for the robot-assisted approach regarding postoperative complications, bleeding, transfusions rate, and length of hospital stay. However, our results appear encouraging regarding the robot-assisted LPN series [4–6,22].

The costs associated with the use of robot-assisted surgery are expensive. It could be interesting to compare them to those related to the use of a HOR.

Our study is of course not without limitations. It is a descriptive study and the different comparisons with other surgical approaches, particularly robot-assisted, may be debatable. No conclusion can be drawn about the superiority of one technique over another.

However, the main strength of our study is being in a real-life prospective setting. It represents the activity of our academic department and the surgical procedures were performed by operators with different levels of experience, some of whom were just beginning their learning curve in laparoscopy.

5. Conclusions

This descriptive study shows that laparoscopic partial nephrectomy after hyperselective embolization of tumor vessels in a hybrid operative room is a feasible, reproducible, and safe approach to treat localized kidney tumors. Further prospective studies could be carried-out to confirm these results.

Author Contributions: Conceptualization, Ulysse Frantz and Pierre Bigot; Methodology, Pierre Bigot; Formal Analysis, Ulysse Frantz and Pierre Bigot; Investigation, Antoine Bouvier, Merzouka Zidane and Pierre Bigot; Writing – Original Draft Preparation, Ulysse Frantz; Writing – Review & Editing, Souhil Lebdaï, Thibaut Culty and Pierre Bigot; Supervision, Pierre Bigot.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

References

1. The Global Cancer Observatory.
2. Bigot P, Barthelemy P, Boissier R, et al. French AFU Cancer Committee Guidelines - Update 2022-2024: management of kidney cancer. *Prog En Urol.* 2022;32(15):1195-1274. doi:10.1016/j.purol.2022.07.146
3. Ljungberg B, Albiges L, Abu-Ghanem Y, et al. European Association of Urology Guidelines on Renal Cell Carcinoma: The 2022 Update. *Eur Urol.* 2022;82(4):399-410. doi:10.1016/j.eururo.2022.03.006
4. French Committee of Urologic Oncology (CCAFU), Peyronnet B, Seisen T, et al. Comparison of 1800 Robotic and Open Partial Nephrectomies for Renal Tumors. *Ann Surg Oncol.* 2016;23(13):4277-4283. doi:10.1245/s10434-016-5411-0
5. Ingels A, Bensalah K, Beauval JB, et al. Comparison of open and robotic-assisted partial nephrectomy approaches using multicentric data (UroCCR-47 study). *Sci Rep.* 2022;12(1):18981. doi:10.1038/s41598-022-22912-8

6. Choi JE, You JH, Kim DK, Rha KH, Lee SH. Comparison of Perioperative Outcomes Between Robotic and Laparoscopic Partial Nephrectomy: A Systematic Review and Meta-analysis. *Eur Urol*. 2015;67(5):891-901. doi:10.1016/j.eururo.2014.12.028
7. Porpiglia F, Bertolo R, Amparore D, Fiori C. Margins, ischaemia and complications rate after laparoscopic partial nephrectomy: impact of learning curve and tumour anatomical characteristics: MIC rate after LPN. *BJU Int*. 2013;112(8):1125-1132. doi:10.1111/bju.12317
8. Simone G, Papalia R, Guaglianone S, Carpanese L, Gallucci M. Zero Ischemia Laparoscopic Partial Nephrectomy After Superselective Transarterial Tumor Embolization for Tumors with Moderate Nephrometry Score: Long-Term Results of a Single-Center Experience. *J Endourol*. 2011;25(9):1443-1446. doi:10.1089/end.2010.0684
9. D'Urso L, Simone G, Rosso R, et al. Benefits and shortcomings of superselective transarterial embolization of renal tumors before zero ischemia laparoscopic partial nephrectomy. *Eur J Surg Oncol EJSO*. 2014;40(12):1731-1737. doi:10.1016/j.ejso.2014.08.484
10. Benoit M, Bouvier A, Bigot P. Salle hybride: pour quoi faire? *Prog En Urol*. 2017;27(14):841-844. doi:10.1016/j.purol.2017.07.001
11. Bigot P, Bouvier A, Panayotopoulos P, Aubé C, Azzouzi AR. Partial nephrectomy after selective embolization of tumor vessels in a hybrid operating room: A new approach of zero ischemia in renal surgery: Hybrid Operating Room for Kidney Surgery. *J Surg Oncol*. 2016;113(2):135-137. doi:10.1002/jso.24120
12. Panayotopoulos P, Bouvier A, Besnier L, et al. Laparoscopic partial nephrectomy following tumor embolization in a hybrid room. Feasibility and clinical outcomes. *Surg Oncol*. 2017;26(4):377-381. doi:10.1016/j.suronc.2017.07.012
13. Aubert C, Rolley C, Mauny M, et al. Évaluation de l'utilisation de la salle hybride sur l'activité de chirurgie en cancérologie rénale. *Prog En Urol*. 2020;30(5):288-295. doi:10.1016/j.purol.2020.02.003
14. Bréhier G, Bouvier A, Besnier L, et al. Renal function after partial nephrectomy following intra-arterial embolization of renal tumors. *Sci Rep*. 2020;10(1):21352. doi:10.1038/s41598-020-78461-5
15. Delahunt B, Srigley JR, Egevad L, Montironi R. International Society of Urological Pathology Grading and Other Prognostic Factors for Renal Neoplasia. *Eur Urol*. 2014;66(5):795-798. doi:10.1016/j.eururo.2014.05.027
16. Kutikov A, Uzzo RG. The R.E.N.A.L. Nephrometry Score: A Comprehensive Standardized System for Quantitating Renal Tumor Size, Location and Depth. *J Urol*. 2009;182(3):844-853. doi:10.1016/j.juro.2009.05.035
17. Clavien PA, Barkun J, de Oliveira ML, et al. The Clavien-Dindo Classification of Surgical Complications: Five-Year Experience. *Ann Surg*. 2009;250(2):187-196. doi:10.1097/SLA.0b013e3181b13ca2
18. Bouvier A, Besnier L, Paisant A, et al. Blue Dye Embolization of Renal Tumor: A New Technique to Improve Tumor Localization During Laparoscopic Partial Nephrectomy. *J Laparoendosc Adv Surg Tech*. 2020;30(3):299-303. doi:10.1089/lap.2019.0686
19. The CCAFU members, Pignot G, Méjean A, et al. The use of partial nephrectomy: results from a contemporary national prospective multicenter study. *World J Urol*. 2015;33(1):33-40. doi:10.1007/s00345-014-1279-4
20. Gill IS, Kavoussi LR, Lane BR, et al. Comparison of 1,800 Laparoscopic and Open Partial Nephrectomies for Single Renal Tumors. *J Urol*. 2007;178(1):41-46. doi:10.1016/j.juro.2007.03.038
21. Simmons MN, Chung BI, Gill IS. Perioperative Efficacy of Laparoscopic Partial Nephrectomy for Tumors Larger than 4cm. *Eur Urol*. 2009;55(1):199-208. doi:10.1016/j.eururo.2008.07.039
22. Masson-Lecomte A, Bensalah K, Seringe E, et al. A prospective comparison of surgical and pathological outcomes obtained after robot-assisted or pure laparoscopic partial nephrectomy in moderate to complex renal tumours: results from a French multicentre collaborative study: Outcomes after robot-assisted or pure laparoscopic partial nephrectomy. *BJU Int*. 2013;111(2):256-263. doi:10.1111/j.1464-410X.2012.11528.x
23. Bravi CA. The IRON Study: Investigation of Robot-assisted Versus Open Nephron-sparing Surgery. Published online 2023.
24. Hidas G, Lupinsky L, Kastin A, Moskovitz B, Groshar D, Nativ O. Functional Significance of Using Tissue Adhesive Substance in Nephron-Sparing Surgery: Assessment by Quantitative SPECT of 99m Tc-Dimercaptosuccinic Acid Scintigraphy. *Eur Urol*. 2007;52(3):785-790. doi:10.1016/j.eururo.2006.12.001
25. George AK, Herati AS, Srinivasan AK, et al. Perioperative outcomes of off-clamp vs complete hilar control laparoscopic partial nephrectomy: Off-clamp vs complete hilar control LPN. *BJU Int*. 2013;111(4b):E235-E241. doi:10.1111/j.1464-410X.2012.11573.x
26. Mir MC, Ercole C, Takagi T, et al. Decline in Renal Function after Partial Nephrectomy: Etiology and Prevention. *J Urol*. 2015;193(6):1889-1898. doi:10.1016/j.juro.2015.01.093
27. Khalifeh A, Autorino R, Eyraud R, et al. Three-year Oncologic and Renal Functional Outcomes After Robot-assisted Partial Nephrectomy. *Eur Urol*. 2013;64(5):744-750. doi:10.1016/j.eururo.2013.03.052
28. Thompson RH, Lane BR, Lohse CM, et al. Every Minute Counts When the Renal Hilum Is Clamped During Partial Nephrectomy. *Eur Urol*. 2010;58(3):340-345. doi:10.1016/j.eururo.2010.05.047

29. Branger N, Bigot P, Pignot G, et al. Oncocytoma on renal mass biopsy: is it still the same histology when surgery is performed? Results from UroCCR-104 study. *World J Urol.* 2023;41(2):483-489. doi:10.1007/s00345-022-04261-3
30. Baboudjian M, Moser D, Yanagisawa T, et al. Benefit and Harm of Active Surveillance for Biopsy-proven Renal Oncocytoma: A Systematic Review and Pooled Analysis. *Eur Urol Open Sci.* 2022;41:8-15. doi:10.1016/j.euros.2022.04.009

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.