

Three-dimensional laparoscopic partial nephrectomy for renal hilar tumors: an empirical analysis of 290 patients

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Research

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Abstract

Objective

To explore the feasibility of laparoscopic partial nephrectomy(LPN) in the treatment of renal hilar tumors.

Methods

Clinical data of 290 patients undergoing laparoscopic partial nephrectomy from January 2013 to August 2019 were retrospectively analyzed, including 27 patients with renal hilar tumors and 263 patients with non-hilar renal tumors. Perioperative data and follow-up results were compared between the two groups.

Results

Tumor size in Group A is smaller(2.97 ± 0.88 vs 3.55 ± 1.46 , $p<0.05$), R.E.N.A.L. nephrometry score of Group A is higher(8.4 ± 1.3 vs 6.5 ± 1.7 , $p<0.01$).The operation time, WIT and intraoperative blood loss in the Group A were slightly higher, but with no statistical difference ($p>0.05$). There was no significant difference between the two groups in intraoperative ultrasound rate, collection system repair rate, drainage time,postoperative hospital stay, and eGFR changes ($p>0.05$).The median follow-up period was 40 months. One patient with postoperative pathologic report of angiomyolipoma was found tumor recurrence and was currently undergoing regular reexamination.

Conclusion

Three-dimensional laparoscopic partial nephrectomy for renal hilar tumors is safe and feasible after detailed preoperative evaluation of the tumor and selection of appropriate surgical strategies.

Introduction

Nowadays, partial Nephrectomy has been the gold standard treatment for T1 stage renal tumors. Compared with open surgery, laparoscopic partial nephrectomy (LPN) often accompanies with less postoperative analgesia and shorter convalescence[1]. Meanwhile, with the development of surgical instruments and improvement of surgeons' technique, some more complicated tumors can be taken into consideration with LPN. Renal hilar tumor, because of its unique anatomic location-adjacent to renal vessels and urinary collecting system, which means more carefully incision, longer warm ischemia time(WIT),longer operative time, and more blood loss[2, 3], is an important type of complex renal tumor. In earlier period of application of LPN in hilar tumors,the operation often associates with high rate of complications[4, 5]. For recent years, with more surgical experience accumulated, the incidence of complications has been reduced to an acceptable level, several retrospective studies have confirmed the feasibility and equivalent oncologic outcomes of LPN for hilar lesions[2, 3, 6].

Robotic partial nephrectomy (RPN) are not yet widely available,LPN still holds the mainstream.3D laparoscopy, with better vision, which has obvious advantages over traditional 2D laparoscopy, can

provide better clinical and surgical outcomes.

Since 2013, we performed three-dimensional laparoscopic partial nephrectomy (3DLPN) for the treatment of renal tumors, and have gained some experience in treatment for hilar tumors. The present study aims to describe our technique and introduce our experiences in 3DLPN for the treatment of hilar renal tumors.

Materials And Methods

Patients

A retrospective review that has been approved by the ethics committee has been performed in Beijing Chaoyang Hospital. We reviewed 290 patients with preoperative imaging (enhanced CT or MRI), from January 2013 to August 2019. According to preoperative imaging, patients were stratified into two groups: the hilar renal tumor group (group A) and non-hilar renal tumor group (group B). We defined hilar renal tumor as renal lesions in direct contact with the renal artery, vein, or both, as identified by preoperative imaging and confirmed intraoperatively[6].

Preoperative parameters included age, gender, body mass index (BMI), R.E.N.A.L. nephrometry scores[7], and preoperative eGFR. Intraoperative information such as surgery approach, utility of intraoperative laparoscopic ultrasonography, operative time, estimated blood loss, and warm ischemia time (WIT) were collected. Postoperative data including postoperative hospital stay, drainage tube retention keeping time, pathology, positive margin status, complications (classified by the Clavien-Dindo grading system) and postoperative eGFR were reviewed. eGFR was estimated by MDRD method, $eGFR = 175 \times \text{creatinine}^{-1.154} \times \text{age}^{-0.203} [\times 0.742 (\text{female})]$ [8].

The surgeries were all accomplished by same surgeon, Nianzeng Xing, with different assistants. Perioperative data were collected by two doctors. For more accurate results, discussion was necessary if there exists disagreement.

Surgical procedures of three-dimensional laparoscopic partial nephrectomy(3DLPN)

All surgeries were accomplished with three-dimensional laparoscopic partial nephrectomy. We adopted two invasive approaches- retroperitoneal and transperitoneal, according to the tumor location and previous relevant surgery history.

A. Retroperitoneal three-dimensional laparoscopic partial nephrectomy.

RLPN were performed as described before[9]. After general anesthesia, ureteral stent is placed for the tumor near the hilar with the guidance of cystoscopy in dorsal lithotomy position. Then patient was placed in lateral decubitus position. The trocars were placed as follows: trocar A (12mm) is placed at the lateral border of erector spinae muscle 2cm below the 12th rib; trocar B (10mm) is placed 2cm above iliac crest at midaxillary line; trocar C (5mm) is placed 2cm below costal margin at anterior axillary line; If

necessary, trocar D (12mm) can be placed 2-3cm ventrally by trocar B, at the same horizontal plane as trocar B. 3D laparoscope was placed in trocar B.

With trocar placed and retroperitoneal space established, Gerota's fascia was opened with ultrasound knife. According to the preoperative imaging, we can generally determine the location of tumor. For completely intraparenchymal tumors and those hard to confirm intraparenchymal boundary, intraoperative laparoscopic ultrasonography can assist in identifying tumor boundary and tumor blood supply, then mark the surface of kidney with electric hook or ultrasound knife. Afterwards, renal artery is dissected and mobilized gently, and we need figure out if there's accessory renal artery. As far as vessel clamping technique is concerned, we adopted four ways: artery-clamping, renal pedicle clamping, segmental clamping and non-clamping. With artery clamping or not, the tumor was resected or enucleated by scissor. For the renal renorrhaphy, we adopted running self-retaining barbed suture with double-layer reconstruction: 3-0 Vicryl in inner plane or renal pelvis and 2-0 Vicryl in outer plane. When suture was finished, for those suspected of collecting system damage, methylene blue was irrigated into renal collecting system to make sure there's no leak. And ultrasonography was used to confirm renal parenchyma blood supply. Drainage tube placement or not depended on operative process.

B. Transperitoneal three-dimensional laparoscopic partial nephrectomy.

After general anesthesia, ureteral stent might be placed as mentioned above. Then patient was placed in flank position at about 70°. Trocars were placed as follows: trocar A (12mm) is placed at peri-umbilicus; trocar B (5mm) is placed 2cm below costal margin at midclavicular line; trocar C (12mm) is placed at the midpoint of the line of anterior superior iliac spine and umbilicus; trocar D (5mm) is placed at the cross of anterior axillary line and umbilical horizontal line. 3D laparoscope was placed in trocar A.

The lateral peritoneum was opened with ultrasonic knife, and the splenorenal ligament or the hepatorenal ligament were dissected. Then the colon and mesocolon was mobilized and pushed to the contralateral abdominal cavity. The renal hilar was dissected, and the renal artery was found by mobilization for clamping. Location of tumor, utilization of ultrasonography, vessel clamping and renal renorrhaphy are consistent with the way of retroperitoneal LPN. Similarly, drainage tube placement or not depended on operation process.

Statistical methods

The data were presented as mean standard deviation for the continuous variables with normal distribution and median and interquartile range for those not. $P < 0.05$ indicated statistical significance. Statistical analysis was completed by Statistical Package for the Social Science, version 21.0.

Results

From 2013-2019, 290 patients who received 3DLPN were reviewed. Among the patients, 182 were male, 146 were lesions on left lateral. Of all the 290 patients, 27 patients had a renal lesion, and 263 had non-

hilar lesion. There is no significant difference in age, BMI, gender, laterality and preoperative eGFR (Table 1).

Intraoperative and postoperative characters of two groups are shown in Table 2. Tumor size in Group A is smaller 2.97 ± 0.88 vs 3.55 ± 1.46 $p < 0.05$, R.E.N.A.L. nephrometry score of Group A is higher 8.4 ± 1.3 vs 6.5 ± 1.7 $p < 0.01$, 48.1% (13/27) of patients in Group A and 13.7% (36/263) of patients in Group B are endophytic, respectively ($p < 0.01$). All 290 cases were successfully completed without conversion to radical or open surgery. In terms of the choice of surgical approach, the choice of intraperitoneal approach in the Group A was significantly higher (25.9% vs 4.9%, $p < 0.05$). The operation time, WIT and intraoperative blood loss in the Group A were slightly higher, but with no statistical difference ($p > 0.05$). We made statistics on the methods of vessel clamping for the two groups, as shown in table 2. One patient in Group A received non-clamping plus "pre-suture" technique, compared to 18 patients (6.8%) in Group B. There was no statistical difference in the estimated blood loss between two groups. However, after excluding the patients in the two groups who underwent non-clamping technique, we reassessed the blood loss in the two groups and found that the blood loss in Group A is more than that in Group B (89.6 ± 61.9 , 62.3 ± 61.0 , $P < 0.05$). In addition, there were no significant differences between the two groups in intraoperative ultrasound rate, collection system repair rate, drainage time, postoperative hospital stay, and eGFR changes ($p > 0.05$).

Pathology information are shown in Table 3, 77.8% (21/27) of patients in Group A and 84.8% (223/263) of patients in Group B are malignant, respectively ($p > 0.05$). All 27 patients in Group A have negative surgical margins, while 3 patients in Group B had positive surgical margins (1.14%) (Table 3).

Short-term complications: two patients (7.4%) in Group A had short-term complications. One patient was diagnosed with urinary leakage due to high creatinine level in postoperative test of drainage fluid, and the indwelling time of drainage tube was prolonged. Postoperative urinary tract infection was diagnosed in 1 case, and was treated with anti-infection. Short-term complications occurred in 12 patients (4.6%) in Group B. 2 patients with postoperative fever and 2 patients with wound pain recovered after relevant treatment. 4 patients were diagnosed with urinary leakage, and indwelling time of drainage tube was prolonged; after treatment, 3 patients recovered, 1 patient received radical nephrectomy for detection of hydronephrosis caused by UPJO. 3 patients showed progressive decrease of hemochrome after surgery, 1 patient received conservative treatment of immobilization, and 2 patients received blood transfusion, with 400ml and 1200ml, respectively. One case of pulmonary infection was cured after anti-infection treatment. There were no long-term complications. There was no significant difference in the incidence of complications between the two groups ($p > 0.05$).

The median follow-up time was 40 (3-82) months, 19 patients were lost to follow-up, 1 case in hilar tumor group, while 18 cases in non-hilar tumor group. There was no metastasis or recurrence in hilar tumor group, and 2 cases relapsed in non-hilar tumor group. 1 patient was found lung metastasis and received targeted therapy, 1 patient with postoperative pathological report of angiomyolipoma had a recurrence and was currently undergoing regular observation.

Table 1
Preoperative information

variables	Group A,n = 27	Group B,n = 263	P value
Age,years	51.6 ± 13.7	53.0 ± 12.1	0.569
BMI ,kg/m ²	25.79 ± 3.12	25.76 ± 3.83	0.969
Gender, n (%)			0.693
Male	16(59.3)	166(62.1)	
Female	11(40.7)	97(36.9)	
Laterality, n (%)			0.331
left	16(59.3)	130(49.4)	
right	11(40.7)	133(50.6)	
Preoperative eGFR, ml/(min.1.73 m ²)	91.9 ± 26.0	97.5 ± 31.4	0.368

Table 2
Intraoperative and postoperative information

variables	Group A,n = 27	Group B,n = 263	P value
Tumor size,cm	2.97 ± 0.88	3.55 ± 1.46	0.045
R.E.N.A.L. nephrometry score	8.5 ± 1.2	6.5 ± 1.7	0.000
Depth of penetration, n (%)			0.000
Exophytic	3(11.1)	108(41.1)	
Mesophytic	11(40.7)	119 (45.2)	
Endophytic	13(48.1)	36(13.7)	
Operative time,min	83.0 ± 31.5	80.4 ± 26.2	0.627
Warm ischemia time,min	19.8 ± 4.7(26)	18.6 ± 5.5(245)	0.300
Estimated blood loss ,mL	90.0 ± 60.7	66.0 ± 65.2	0.067
Estimated blood loss(Artery clamping),mL	89.6 ± 61.9	62.3 ± 61.0	0.031
Surgical approach(%)			
transperitoneal	7(25.9)	13(4.9)	0.000
retroperitoneal	20 (74.1)	250 (95.1)	
Intraoperative ultrasonography,n(%)	14 (51.9)	112 (42.6)	0.355
Collection system repair,n(%)	3 (11.1)	13 (4.9)	0.371
Artery clamping technique			
Artery clamping	25	238	-
Renal pedicle clamping	1	1	
Segmental clamping	0	6	
Non-clamping	1	18	
Drainage time,d	4.6 ± 1.8	4.6 ± 2.4	0.970
Postoperative hospital stay,d	6.3 ± 2.2	5.9 ± 2.2	0.408
Postoperative complications, n(%)	9 (8.7)	6 (6.5)	0.602
Postoperative eGFR, ml/(min.1.73 m ²)	84.9 ± 25.0	89.7 ± 28.9	0.409
eGFR changes,ml/(min.1.73 m ²)	-7.0 ± 6.3	-7.8 ± 6.2	0.487
Surgical margin status, n(%)	0 (0.00)	3 (1.14)	

Table 3
Postoperative complications and treatment

	Group A,n = 27	Group B,n = 263	Treatment
Early complications(≤30 d)			
Incision pain	0	2	Conservative
fever	0	2	Conservative
Urinary infection	1	0	Antibiotics
fistula	1	4	Conservative,
bleeding	0	3	transfusion for 2 cases and conservative treatment for 1case
Pulmonary infection	0	1	Antibiotics
90-d complications			
none			

Table 4
Postoperative pathplogy

variables	Group A	Group B
pathology, n	27	263
clear-cell RCC	19	193
chromophobe RCC	2	15
papillary RCC	0	9
multilocular cystic RCC	0	3
Xp11.2 translocation RCC	0	3
angiomyolipoma	5	29
cncocytoma	1	7
adenofibroma	0	1
perimyocyte tumor	0	1
renal cyst	0	2

Discussion

Renal hilar tumor is a kind of complicated renal tumor. Because of its adjacent to vessels or urinary collection system, it's difficult for tumor excision and renorrhaphy, which means longer operation time and WIT. Meanwhile, LPN for hilar tumors always associates with higher incidence of complications, especially bleeding and fistula[10]. Gill[4] evaluates results of LPN for hilar tumors in 8 patients, found that nine complications was developed in 6 patients, including hemorrhage in 1 and urine leak in 4. In Richstone's study of LPN for hilar tumors, postoperative transfusion was required in 4 patients(22.2%)[5]. With feasibility of LPN for hilar tumors confirmed, shortening WIT and surgery-related complications has been the goal of urologists. The purpose of this article is to introduce the efficacy and experience of 3DLPN in the treatment of renal hilar tumors in our center.

In comparison with character of tumors, we found that hilar tumors were smaller than non-hilar tumors. Contrary to our study, some studies found that tumors at the hilum were larger[3, 11-13]. Dulabon[13] think hilar tumors' larger size may be ascribed to the tumor's proximity to major blood vessels, which could provide more blood supply to facilitate tumor growth. We found that a higher proportion of patients with hilar tumors were typed with endogenous growth, with 48.1% of patients being endophytic, significantly higher than that of non-hilar group, consistent with George's study[6]. We thought high proportion of endogenous growth may relate with smaller size of renal tumors in our study. As for pathology, Dulabon[13] found that hilar renal tumors are associated with higher risk of malignancy, whereas, Lu[12] and Correa[11] found no difference between hilar and non-hilar tumors regarding the incidence of malignancy, neither in our study.

When handling hilar tumors, the risk of bleeding caused by injured blood vessels and damage to the collection system is higher than that of tumors at other locations. Therefore, it often takes more time for tumor excision and renorrhaphy, which is most intuitively shown by longer operation time, greater WIT and blood loss. There's study indicate that hilar tumor is the independent predictor for WIT[2]. With the development of medical equipment and improvement of surgical skill, the mean WIT of most studies has been limited in 30 mins(18-27)[2, 3, 13], an acceptable range. In the present study, there's no difference concerning the operation time, WIT, intraoperative blood loss and complication rate between two groups, and mean WIT in hilar tumor group is 19.8 mins, close to the result of RLPN[3]. Our result has confirmed the safety and feasibility of 3DLPN for renal hilar tumors.

In partial nephrectomy, the two main goals we need to achieve are ensuring negative surgical margin and reserving renal function. It has been reported that post-PN renal function is associated with multiple factors: kidney quality, remnant quantity, ischemia type and duration[10]. In order to shorten the duration of ischemia and retain renal parenchyma as much as possible, we believe that the following aspects in LPN are helpful to achieve our goals: 3D laparoscopic vision, imaging support of intraoperative ultrasound, vascular control techniques, and self-retaining barbed suture.

3D laparoscopy can provide stereoscopic vision, overcoming the shortcoming of the lack of spatial sense of 2D, and have a better identification of local anatomy. A META analysis comparing the application of 2D and 3D laparoscopy in urological surgery, they found that 3D LPN has significantly shorter WIT[14].

Especially for the tumor at the hilum, the three-dimensional sense of space and fine surgical images are helpful to confirm the boundary between the tumor and the blood vessels, so as to avoid damage to the blood vessels in the process of tumor resection. In the present study, the WIT in hilar tumor group was 19.8min. On the one hand, the results may be ascribed to surgeon's abundant laparoscopic experience, on the other hand, the advantages brought by 3D laparoscopy can not be ignored.

As described in the surgical procedures, surgeon will adopt different vascular clamping methods according to the comprehensive information of tumor location, size, penetration degree, blood supply, etc. In the present study, 19 patients were treated with non-clamping approach, only 1 case in hilar tumor group. Non-clamping technique is suitable for tumor with less-complicated anatomic features, such as small size, exophytic lesion, low nephrometry scores[10]. Considering high nephrometry scores and less exophytic lesions (3/27) in hilar tumor group, application of non-clamping is restricted in the present study. In George's study[6], 20.9% (9/43) of patients underwent non-clamping technique, avoiding damage to renal function caused by WIT. For selected hilar tumors, non-clamping technique should be advocated for better prognosis. Non-clamping relates to high risk of bleeding, especially when the tumor in the renal parenchyma is excised. We pre-suture renal parenchyma around the tumor boundary to block the tumor blood supply before resection, which effectively reduced wound bleeding.

In order to evaluate tumor's blood supply and anatomic relationship with vascular and collecting system, sometimes, we need assistance of intraoperative ultrasound. Moreover, we found that a considerable number of hilar tumors were endogenous, and it is vital to clarify the status of intramedullary tumors. It has been reported that ultrasound can clearly show the tumor boundary, and with the help of ultrasound, the surgeon can retain as much renal parenchyma as possible on the premise of negative surgical margin, which is of positive significance for the recovery of postoperative renal function[15]. During the suture of renal parenchyma, blood vessels may be ligated, resulting in ischemia of partial remaining renal parenchyma. With ultrasound's evaluation, we can take measures in time in case ischemia exists, which is meaningful for renal function preservation.

Efficient renorrhaphy is very important for shortening WIT and reducing postoperative complications. We adopted running, self-retaining barbed suture with double-layer reconstruction. A review[16] concerning suture techniques for laparoscopic and robotic partial nephrectomy found that: 1) compared with interrupted suture, running suture can shorten the operation time, WIT and the incidence of postoperative complications. 2) compared with non-barbed suture, barbed suture can shorten the operation time, WIT and reduce blood loss. We have also reported that self-retaining barbed suture method can improve suture efficiency and shorten WIT. For renal parenchymal reconstruction with hilar tumor, new technologies such as "V-hilar suture technique"[17] and "ring suture technique"[18] have been reported, and good clinical results have been achieved.

For tumors in different locations, choosing an appropriate surgical approach can reduce the difficulty of the operation, and the surgeon will be more proficient in handling tumors. When the renal tumor is located in the ventral region or the tumor volume is large, the peritoneal approach can provide a larger operating

space, which is a more appropriate choice. In this study, 25.9% of patients with hilar tumor were treated by transperitoneal approach, significantly higher than 4.9% of patients with nonhilar tumor. In treatment of hilar tumors, transperitoneal LPN sometimes can be more convenient. We thought hilar tumor is more often located on the medial of the kidney, thus it is more possible that tumors are on ventral region. Similarly, Sunaryo's study[3] also showed a significant difference related to tumor location for hilar and non-hilar tumors (48.8% vs 36.2% anterior).

Hemorrhage and urinary leakage are the most common complications in hilar renal tumors. In this study, the complication rate in the renal hilar tumor group was 7.4%, there was no occurrence of hemorrhage or urine leakage. On the one hand, 3D laparoscopy and intraoperative ultrasound can provide better image of anatomical relationship, thus reduce the chance of damage to blood vessels and collecting system. On the other hand, it makes examination of collecting system more convenient with the use of ureteral stents. During postoperative follow-up, we found that there was no significant difference in eGFR between the two groups 3-month postoperatively. George[6] explored the oncologic and renal function results of LPN for hilar tumors, and found no significant difference in creatinine 6 months after surgery compared with non-hilar tumors. These findings prove the feasibility and safety of LPN for the treatment of hilar renal tumors.

The present study has some defects and deficiencies. This study is a single-center retrospective study with a small sample, and the results obtained need to be further verified by larger prospective studies. Renal function was not assessed with the aid of nephrogram or other adjunctive examination, and the eGFR was estimated by creatinine values, compensatory function of the normal contralateral kidney would affect the final outcome.

Conclusion

3DLPN for renal hilar tumors is safe and feasible after detailed preoperative evaluation and appropriate surgical strategies. In the absence of robot, three-dimensional laparoscopy is also a good option, which can reduce the difficulty of the operation. Hilar tumors are relatively complex, for LPN, appropriate surgical strategies are required in the selection of body position, clamping technique and renal renorrhaphy.

Abbreviations

LPN, laparoscopic partial nephrectomy; 3DLPN, three-dimensional laparoscopic partial nephrectomy; WIT, warm ischemia time; BMI, body mass index

Declarations

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Availability of data and materials

Data used and/or analyzed in the current research can be obtained from the corresponding author on reasonable request.

Authors' contributions

FY, LM and NX designed the study and edited the manuscript. FY and LM carried out data acquisition and analysis. FY and LM wrote the manuscript. FY and LM collected the clinical information and managed the clinical data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study was approved by the Research Ethics Committee in our hospital (China). Each enrolled patient provided written informed consent. All information was handled following relevant ethical and legal standards.

Consent for publication

Informed consent was obtained from the patients.

Competing interests

The authors declare that they have no competing interests.

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