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Original Article

Comparison of the efficacy between robot-assisted and conventional laparoscopic nephron-sparing surgery for early-stage renal cell carcinoma

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Abstract: Objective: To compare the efficacy of robot-assisted laparoscopic nephron-sparing surgery (RALNSS) with conventional laparoscopic nephron-sparing surgery (LNSS) in patients with early-stage renal cell carcinoma (RCC). Methods: Seventy-five patients with early-stage (T1-T2N0M0) RCC who underwent RALNSS or LNSS from January 2015 to July 2016 were randomly divided into RALNSS group (n=38) or LNSS group (n=37). Measurements including operation time (OT), intraoperative blood loss (IOBL) and renal warm ischemia time (RWIT) were recorded in all surgeries. The patients in each operative group were divided into low-risk, moderate-risk and high-risk groups according to the RENAL nephrometry score, followed by comparation in OT, IOBL and RWIT between corresponding risk groups. All patients were given 2-year follow-up for renal function evaluation. Results: There were no significant differences between the two groups in OT, RWIT and postoperative renal function (all $P>0.05$). The RALNSS group had less IOBL than the LNSS group ($P<0.05$). There was no significant difference in OT, IOBL and RWIT between the two low-risk groups (all $P>0.05$). The OT, IOBL and RWIT in patients with moderate or high risk were better in the RALNSS group than those in the LNSS group with statistical differences (all $P<0.05$). As to 2-year follow-up of renal function, the RALNSS group was superior to the LNSS group ($P<0.05$). Conclusion: In the treatment of complex RCC surgery, RALNSS has shorter RWIT and OT, less IOBL, and better protection for renal function compared to LNSS, suggesting that RALNSS for RCC is worthy of application in clinical practice.

Keywords: Renal cell carcinoma, robot, laparoscopy, nephron-sparing surgery, renal function

Introduction

Renal cell carcinoma (RCC), also known as kidney cancer, is a clinically common malignant tumor in urinary system, and its incidence is second to that of bladder cancer [1]. This disease has a great impact on the quality of life of patients. A survey from the American Cancer Society in 2010 showed that 13,040 cases died of RCC [2]. The Chinese national epidemiological survey of cancer in 2015 showed that the incidence of RCC ranked the 15th among all cancers, and the cancer had no obvious gender orientation with a rising trend in young individuals [3]. Surgery is the main treatment for patients with early-stage RCC. Previously, radical nephrectomy was the standard operating procedure [4]. Nephron-sparing surgery (NSS) and radical nephrectomy have no significant difference in efficacy in recent years [5, 6], while NSS can effectively preserve nephrons and reduce the risk of chronic kidney diseases, so it is promoted for clinical application [7]. Conventional laparoscopic surgery is often clinically applied in NSS. With the development of technology, robot-assisted minimally invasive laparoscopic surgery has emerged as an alternative to the conventional one in clinical practice. Robot-assisted laparoscopic surgery is more precise, which can reduce renal damage and provide accurate dissection and closure to reach an obvious effect especially in the treatment of a complex tumor. Some studies have showed that there was no difference between the two surgeries in terms of renal warm ischemia time (RWIT), while some studies have concluded that robot-assisted laparoscopic nephron-sparing surgery (RALNSS) can significantly reduce RWIT; so the difference in clinical efficacy between the two surgeries is still in exploration [8, 9]. As a relatively good way to evaluate clinical efficacy, this study using a prospective randomized controlled trial method aims to compare the clinical outcomes between RALNSS and conventional laparoscopic nephron-sparing surgery (LNSS) to provide a basis for subsequent clinical trials.

Materials and methods

Baseline characteristics

A total of 75 patients with early-stage RCC who were admitted to the Department of Urology, Beijing Jishuitan Hospital from January 2015 to July 2016 were included. The patients in this study were diagnosed with localized RCC (T1a, T1b) or exophytic RCC (T2a) with in-situ renal mass protruding off the surface of the kidney according to the 2010 AJCC TNM Staging System for Renal Cell Carcinoma. Among the included patients, 43 were male and 32 were female, and their age ranged from 23 to 83 years old with a mean age of 62.6±10.3 years old. All patients were divided into two groups according to the retrospective clinical randomized controlled trial method, RALNSS group (n=38) and LNSS group (n=37). RALNSS group contained 21 males and 17 females with a mean age of 62.0±10.3 years old, within which 25 cases underwent surgery on the left side and 13 cases on the right side. And LNSS group contained 22 males and 15 females with a mean age of 63.2±10.3 years old, within which 21 cases underwent surgery on the left side and 16 cases on the right side. All patients were followed up for renal function evaluation in the following 2 years after treatment. The study was approved by the Medical Ethics Committee of Beijing Jishuitan Hospital, and informed consents were obtained from all the patients.

Inclusion and exclusion criteria

Inclusion criteria: Patients diagnosed as unilateral early-stage RCC according to the diagnostic criteria proposed by AJCC TNM Staging System for Renal Cell Carcinoma in 2010 [10]; their ages ranged from 23 to 83 years old; their clinical data were complete and reports well-documented; postoperative pathological diagnosis showed no lymph node metastasis and co-morbidities.

Exclusion criteria: 1) Patient who had bilateral renal tumor, solitary kidney, or unilateral renal tumor with multiple masses; 2) patient who had RCC complicated with ipsilateral perirenal lymphadenectasis, perirenal fat invasion, inferior vena cava thrombosis, or adrenal metastasis without distant metastasis; 3) patient who had anatomic variation or abnormal congenital development like duplex kidney as well as severe heart, liver, kidney or other diseases; 4) patient who received radiotherapy and chemotherapy; 5) patients whose blood test showed obvious abnormalities; and 6) patients who was not suitable for the two surgeries or had difficulty or inconvenience in follow-up.

Operation process of conventional laparoscopic nephron-sparing surgery

All patients received LNSS under general anesthetic. Detailed steps were as follows [5]: the patients were ventilated with oxygen under a face mask at a rate of 6-8 L/min. Anesthesia was induced intravenously with 0.05-0.10 $mg.kg^{-1}$ of midazolam injection (Jiangsu Nhwa, China), 1-1.5 $mg.kg^{-1}$ of propofol injection (Xi'an LIBANG, China), 0.2-0.3 $\mu g.kg^{-1}$ of sufentanil citrate injection (Yichang Humanwell, China) and 0.15-0.2 $mg.kg^{-1}$ of shun atracurium (Jiangsu Hengrui, China). After assisted respiration for 3 min, laryngoscopy and tracheal intubation was performed. Administration of 10-20 μg of sufentanil citrate injection was performed 5 min before skin incision. Following successful anesthesia, the patients were placed on the normal side in the lateral decubitus position with the surgical monitor connected to the patients for monitoring vital signs; then the waist bridge was heightened, and disinfection on the operative site and placement of sterile sheets and towels were performed. A high-definition laparoscopic operating system (Karl Storz, Germany) was launched firstly for the later operation. A 10-mm incision for placing the first Trocar (Johnson & Johnson, USA) was made along the cleavage lines about 10 mm below the junction of the lower costal margin of the 12th rib in posterior axillary line. We used forceps to bluntly dissect the subcutaneous tissues like the muscular layer and lumbo-dorsal fascia for less cutting of muscle without compromising the opening of the fascia. Retroperitoneal fat was dissected by index finger, and a balloon-dilator was placed in the gap created by the preceding dissection. Then 800 mL air was inflated into the balloon-dilator to distract the retroperitoneum for enough working space. The second Trocar was inserted 20 mm above the superior border of the iliac crest in the mid-axillary line and the third Trocar inserted about 10 mm below the junction of the lower costal margin below the 12th rib in posterior axillary line. The skin incision was then sutured to fix the three Trocars in the right places to create a pneumoperitoneum for working space.

The peripheral fat of the surgical site was dissected by Ultracision-Harmonic Scalpel (Karl Storz, Germany) and bluntly dissected by vessel forceps in order to enlarge the peritoneal space for the operations. Then the dissection was taken in the Gerota's fascia along the psoas major muscle to get to the dorsal surface of the kidney and to the renal hilum for sufficiently exposing the renal artery. Following clearly exposure, the tumors were found and fully mobilized according to the imaging report. A non-invasive blood vessel clamp (Karl Storz, Germany) was then inserted into the cavity through a Trocar to completely block the renal artery. Subsequent to the blocking, the tumor was separated from the reserved medullary and medullary ray to the depth of the basement membrane. Then interrupted suture and ligation were performed using the absorbable 3-0 suture (Weck, USA) about 5 mm away from the incision margin of the mass, followed by running suture with absorbable 3-0 unidirectional barbed suture (Weck, USA) on the renal parenchyma to a complete suture of the incision. After all the sutures were completed and fixed well, the blood vessel clamp was released and the presence or absence of bleeding was checked. After confirming that there was no active bleeding on the surgical wound when pneumoperitoneum pressure was decreased, and that all the surgical items were taken out of the surgical site, a drainage tube was placed at the second puncture site, and sterile dressings were applied externally for the closure of all the incisions.

Operation process of robot-assisted laparoscopic nephron-sparing surgery

After successful anesthesia like what did in conventional LNSS, the patients were placed on the normal side in the lateral decubitus position, and the waist bridge was heightened, followed by disinfection on the surgical site and placement of sterile sheets and towels. Selection of surgical sites: A transverse incision of about 12 mm was undergone 4 cm below the costal margin between the midclavicular line and the anterior axillary line on the abnormal side for establishing a pneumoperitoneum. After pneumoperitoneum was achieved, a 12-mm Trocar was placed in the pneumoperitoneum for the robotic camera. After the camera port was placed, two 8-mm Trocars were placed on the ipsilateral side, 5 cm below the costal margin for NO.1 working arm and 3 cm from the anterior superior iliac spine along a line to the umbilicus for NO.2 working arm. A fourth 12-mm Trocar was then placed 5 cm away from the NO.1 working arm in the ipsilateral lower quadrant and a fifth 5-mm Trocar was placed 5 cm away from the NO.2 working arm on the lateral side for auxiliary operation. After all the ports were completed, the working arms were well-adjusted so that they were suitable for the operation; and the camera arm was connected with all the lens ports, followed by proper adjustment for a sufficient operative view [11].

Operation details: 1) Mobilization of kidney. An incision of the lateral peritoneum was performed along the white line of Told to expose the colon. Then the colon was moved to the medial side, followed by cutting of the ligaments that affected operative view to mobilize the kidney and expose the Gerota's fascia completely. 2) Dissection of renal artery and vein. Subsequent to the mobilization of kidney, the renal hilum and its structure were exposed in the concave depression of the medial margin of kidney. Then the renal artery and vein were bluntly dissected in the renal hilum. 3) Identification of tumor. The Gerota's fascia was incised to well expose the kidney, after which the tumor was found, exposed and separated from the surrounding tissues. Then the tumor resection margin was labeled with laparoscopic electric scissors (American Johnson & Johnson). 4) Before removing the tumor, non-invasive blood vessel clamps were used to completely block the renal artery and vein. 5) Dissection of tumor. Dissection of tumor was performed using the electric scissors at about 5 mm away from the incision margin of the mass, during which normal renal tissues were preserved as much as possible. 6) Closure of the wound. A non-invasive blood vessel clamp was then inserted into the cavity through a Trocar to completely block the renal artery. Subsequent to the blocking, the interrupted suture and ligation were performed using the absorbable 3-0 suture (Weck, USA) about 5 mm away from the incision margin, followed by running suture with absorbable 3-0 unidirectional barbed suture (Weck, USA) on the renal parenchyma to a complete suture of the incision. After all the sutures were completed and fixed well, the blood vessel clamp was released and the presence or absence of bleeding was checked. 7) Final operation. Before suturing all the layers incised in the preceding operations, the blood and urine of the surgical area were aspirated out. After reconfirming that there was no active bleeding on the surgical wound when pneumoperitoneum pressure was decreased, and that all the surgical items were taken out of the surgical site, the working arms were removed and the tumor specimen was taken out for pathologic examination. Then all the outer incisions were sutured layer by layer, and sterile dressings were applied externally for the closure of all the incisions.

To ensure the quality of surgery, the followings were complied with: All procedures were performed by seasoned surgeons; the same patch and suture materials were used for the same type of surgery; unified treatment and nursing plan were adopted in both groups of patients before and after surgery; corresponding methods for hemostasis were applied to intraoperative bleeding, and routine prevention of infection was performed for postoperative incisions; the follow-up plans in both groups were the same.

Measurements of surgery

Measurements of both kinds of surgeries included operation time (OT), renal warm ischemia time (RWIT) and intraoperative blood loss (IPBL). The OT was recorded from the incision of the skin to the end of the suture. The time of placement of balloon-dilator and its inflation were not included in the conventional laparoscopy. Likewise, the time for preparing the working arms was not included in the robot-assisted laparoscopic surgery. In both groups, the RWIT was recorded from the blocking of the renal artery and vein to the end of the blockade. The amount of IPBL was recorded from the start of surgery to the end of surgical suture.

Preoperative data

General information of all the patients, tumor size, preoperative hemoglobin, serum creatinine, cystatin C (American Beckman automatic biochemical analyzer) were collected before surgery. Meanwhile, preoperative RENAL nephrometry scoring was performed to assess the complexity of tumor [12]. The score contained six indicators, four parameters and two qualitative descriptions. Each of the four parameters was scored from 1 to 3. The patients were divided into low-risk (4-6 points), moderate-risk (7-9 points) and high-risk (10-12 points) groups according to the RENAL score.

Follow-up measurements

Three follow-ups at 6 months, 1 year, and 2 years postoperatively were carried out. In each follow-up, measurements including blood routine, renal and liver function, chest fluoroscopy, abdominal CT and B-ultrasound were reexamined.

Statistical analysis

The data obtained in this study were analyzed using the SPSS software version 17.0. The continuous variables were expressed as mean ± standard deviation ($\overline{X}$ ± sd). The t-test was performed on the continuous variables that conformed to the normal distribution and the homogeneity of the variance, which was expressed as t. While rank sum test was performed on the continuous variables that did not conform to the normal distribution and the homogeneity of the variance, which was expressed as Z. Enumeration data were expressed as number/percentage (n/%). Pearson chi-square test and Fisher exact probability test were performed on the enumeration data, which were expressed as χ^2. $P<0.05$ is considered statistically significant.

Results

Baseline characteristics

There were 38 cases in the RALNSS group and 37 in LNSS group. There were no significant differences in gender, age, tumor location and tumor size between the two groups (all P>0.05). There were no differences between the two groups in preoperative serum creatinine, hemoglobin, and cystatin C as well as the RENAL nephrometry score, as shown in **Table 1**.

Intraoperative and postoperative measurements

The RALNSS group could save 10 min or more on average compared with the LNSS group in

Table 1. Comparison of baseline characteristics between the two groups

Items	The RALNSS group (n=38)	The LNSS group (n=37)	χ^2/t	P
Gender (male:female)	21:17	22:15	-0.363	0.781
Age (year)	62.0±10.3	63.2±10.3	0.489	0.626
Location of tumor (left:right)	25:13	21:16	0.796	0.429
Tumor size	4.21±0.85	4.33±0.89	-0.603	0.548
Preoperative serum creatinine level	96.29±22.69	95.73±20.99	0.111	0.912
Preoperative hemoglobin level	148.42±21.15	147.89±20.49	0.110	0.913
Preoperative cystatin C level	0.93±0.14	0.94±0.12	-0.140	0.889
The RENAL Nephrometry Score	7.79±2.02	7.73±2.02	0.523	0.603
Risk groups			-0.745	0.457
Low-risk (4-6 points) (case)	8	10		
Moderate-risk (7-9 points) (case)	23	22		
High-risk (10-12 points) (case)	7	5		

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery.

Table 2. Comparison of intraoperative and postoperative related indicators between the two groups

Items	The RALNSS group (n=38)	The LNSS group (n=37)	t	P
Operation time (min)	101.82±37.28	109.24±42.77	-0.802	0.425
Renal warm ischemia time (min)	15.68±4.38	19.00±6.89	-2.032	0.056
Intraoperative blood loss (mL)	32.71±14.96	46.49±24.21	-2.478	0.004
Postoperative hemoglobin level (g/L)	131.21±21.55	130.76±20.10	0.094	0.952
Difference of hemoglobin levels between pre- and post-operation (g/L)	17.21±5.71	17.14±5.76	0.057	0.955
Postoperative serum creatinine level (μmol/L)	113.95±25.66	113.26±23.06	0.120	0.905
Difference of serum creatinine levels between pre- and post-operation (μmol/L)	17.66±9.69	17.54±10.09	0.051	0.959
Postoperative cystatin C level (mg/L)	1.09±0.35	1.10±0.35	-0.084	0.933
Difference of cystatin C levels between pre- and post-operation (mg/L)	0.25±0.31	0.25±0.31	-0.036	0.971

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery.

Table 3. Comparison of operation time, renal warm ischemia time and intraoperative blood loss in the low-risk group between the two groups

Items	The RALNSS group (n=8)	The LNSS group (n=10)	t	P
OT (min)	71.75±5.99	71.70±3.02	0.023	0.982
RWIT (min)	12.38±1.41	12.70±1.49	-0.470	0.645
IOBL (mL)	20.25±3.91	20.80±4.94	-0.256	0.801

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery; OT, operation time; IOBL, intraoperative blood loss; RWIT, renal warm ischemia time.

term of the OT, but there was no statistical difference in the OT between the two groups (P>0.05). The RWIT of the RALNSS group was about 4 min less than the LNSS group, but no statistical difference was shown in the RWIT between the two groups. IOBL in the RALNSS group was reduced by about 14 mL on average compared with the LNSS group, which showed a statistical difference (P<0.05). Postoperative hemoglobin levels, differences of hemoglobin levels between pre- and post-operation, postoperative serum creatinine levels, differences of serum creatinine levels between pre- and post-operation, postoperative cystatin C levels, and differences of cystatin C levels between pre- and post-operation in the two groups showed no significant statistical difference (all P>0.05; **Table 2**).

Operation time, renal warm ischemic time and intraoperative blood loss between two low-risk groups

Comparing the OT, RWIT and IOBL between the two low-risk groups, there were no significant differences in those three measurements (all P>0.05; **Table 3**, **Figure 1**).

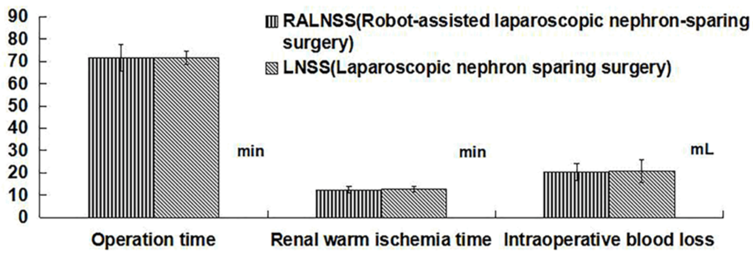

Figure 1. Comparison of operation time, renal warm ischemic time and intraoperative blood loss in low-risk group between the two groups.

Table 4. Comparison of operation time, renal warm ischemia time and intraoperative blood loss in the moderate-risk group between the two groups

Items	The RALNSS group (n=23)	The LNSS group (n=22)	t	P
OT (min)	92.52±13.02	107.18±20.72	-2.855	0.007
RWIT (min)	14.91±2.74	20.18±2.17	-7.116	0.000
IOBL (mL)	29.13±4.66	49.41±15.05	-6.197	0.000

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery; OT, operation time; IOBL, intraoperative blood loss; RWIT, renal warm ischemia time.

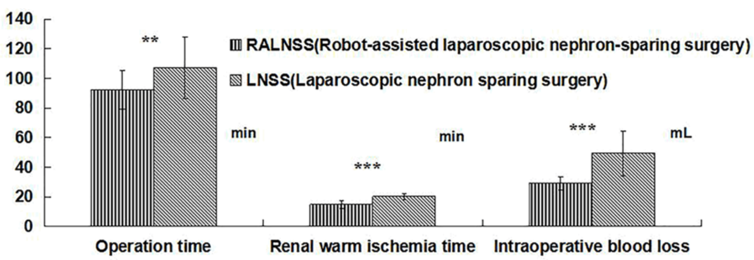

Figure 2. Comparison of operation time, renal warm ischemic time and intraoperative blood loss in moderate-risk group between the two groups. **$P<0.01$; ***$P<0.001$.

Operation time, renal warm ischemic time and intraoperative blood loss in two high-risk groups

About 26 min on average was saved in terms of OT in the RALNSS high-risk group compared with that in the LNSS high-risk group. The RWIT in the high-risk patients of RALNSS group was shortened by about 8 min on average compared with that of LNSS group. And the IOBL in high-risk patients of RALNSS group was reduced by about 34 mL on average compared with that of the LNSS group. There were statistical differences in terms of the three measurements between the two high-risk groups (all $P<0.05$; **Table 5**, **Figure 3**).

Serum creatinine level in follow-up

The patients were followed up for renal function at 6 months, 1 year, and 2 years postoperatively. The RALNSS group was significantly superior to the LNSS group in serum creatinine levels at 6 months, 1 year, and 2 years, which showed statistical differences (all $P<0.05$; **Table 6**, **Figure 4**).

Operation time, renal warm ischemic time and intraoperative blood loss in two moderate-risk groups

OT in the RALNSS moderate-risk group was shortened by about 15 min on average compared with that in the LNSS moderate-risk group. About 5 min on average was saved in terms of RWIT in the RALNSS moderate-risk group compared with that in the LNSS moderate-risk group. And the IOBL in RALNSS moderate-risk group was reduced by about 20 mL on average compared with that in the LNSS moderate-risk group. There were statistical differences in terms of the three measurements between the two moderate-risk groups (all $P<0.05$; **Table 4**, **Figure 2**).

Cystatin C level in follow-up

The patients were followed up for cystatin C levels at 6 months, 1 year, and 2 years postoperatively. The RALNSS group was significantly superior to the LNSS group in cystatin C levels at 6 months, 1 year, and 2 years, which showed statistical differences (all $P<0.05$; **Table 7**, **Figure 5**).

Complications and outcomes

In terms of complication, one case of delayed wound healing and one case of cerebral embolism showed in each operative group. There was no difference in the incidence of complications between the two groups. No metastasis

Table 5. Comparison of operation time, renal warm ischemia time and intraoperative blood loss in the high-risk group between the two groups

Items	The RALNSS group (n=7)	The LNSS group (n=5)	t	P
OT (min)	166.71±38.16	193.40±43.20	-2.541	0.021
RWIT (min)	22.00±5.03	30.00±6.94	-2.323	0.043
IOBL (mL)	50.71±15.77	85.00±21.96	-2.426	0.036

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery; OT, operation time; IOBL, intraoperative blood loss; RWIT, renal warm ischemia time.

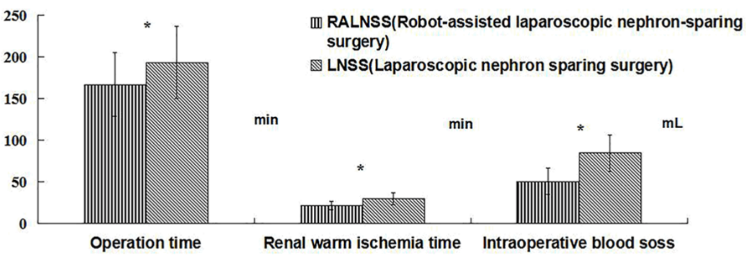

Figure 3. Comparison of operation time, renal warm ischemic time and intraoperative blood loss in high-risk group between the two groups. *P<0.05.

or recurrence was found in the two groups during the 2-year follow-up.

Discussion

Nowadays, RCC has a high incidence with a rising trend in young individuals [1, 3]. And with the use of CT and B-ultrasound, the detection rate of the cancer is greatly increased [13]. Therefore, the treatment and prognosis of this cancer have received more and more attention. Formerly, laparotomy was used as the basic method for the treatment of the cancer. And with the update of technology and the clinical application of minimally invasive surgery in recent years, it has been found that laparoscopic surgery and robot-assisted laparoscopic surgery have no significant difference in the treatment of a cancer compared with laparotomy, and in addition, have advantages of minimal invasion, fast recovery, and good tolerance for patients [14, 15]. But the difference in clinical efficacy between the two minimally invasive surgeries is still inconclusive [8, 9]. As to the difference, this study aimed to compare the clinical efficacy of the two surgeries.

The RENAL score used in this study is a tool for evaluating the complexity of a tumor [12]. After grouping all the patients in both operative groups using the RENAL score, we found that the number of low-risk patients and that of high-risk patients in the RALNSS group differed from those in the LNSS group. So, all the patients were divided into three risk groups to make comparisons between two operative groups. The study found that no significant differences were shown in terms of OT, IOBL and RWIT between the two low-risk groups. However, middle-risk and high-risk patients in the RALNSS group was significantly superior to those in the LNSS group in the above three measurements. The procedures and the anatomical location of the tumor in the low-risk groups were relatively easier than those in the moderate-risk and high-risk groups, so the difference between the two surgeries in the low-risk groups was not obvious. There were significant differences between the two surgical methods in the moderate-risk and high-risk groups, which was closely related to the features and advantages of the two surgeries. In conventional laparoscopic surgery, on the surgeons' side, the display can offer a multi-angle, high-magnification and high-definition surgical visual field, which can clearly expose lesion and tissue structure accurately and radically excise a tumor without damaging normal tissues and organs. So, operations in the conventional LNSS can preserve the nephrons as much as possible with less damage to the body and organs and less OT than an open surgery. And on the patients' side, they can benefit from many aspects such as small trauma, small incision, less pain, less postoperative complications, quick recovery after surgery, less scarring after incision, shorter hospital stay, and lower cost. Compared with the conventional laparoscopic surgery, the robot-assisted laparoscopic surgery has more advantages: 1) the surgeons can conduct the operation in a sitting position, which decreases the work intensity so as to reduce the fatigue, offering more energy and time to the complicated surgery; 2) with the help of high-resolution 3D

Table 6. Comparison of decreases of serum creatinine levels at post-operation, and at post-operative 6 months, 1 year and 2 years between the two groups

Items	The RALNSS group (N=38)	The LNSS group (N=37)	χ^2/t	P
Difference of serum creatinine levels between pre- and post-operation (μmol/L)	17.66±9.69	17.54±10.09	0.051	0.959
Difference of serum creatinine levels between post-operation and post-operative 6 months (μmol/L)	1.79±2.28	13.65±1.63	-25.81	0.000
Difference of serum creatinine levels between post-operative 6 months and post-operative 1 year (μmol/L)	1.92±2.05	6.57±4.38	-5.846	0.000
Difference of serum creatinine levels between post-operative 1 year and post-operative 2 years (μmol/L)	1.32±2.67	8.69±4.59	-8.483	0.000

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery.

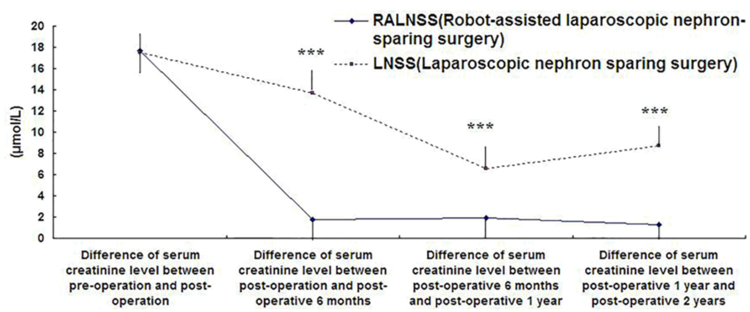

Figure 4. Tendency chart of the decreases of the serum creatinine levels at post-operation, and at post-operative 6 months, 1 year and 2 years. ***P<0.001.

imaging system, the visual field is clearer and the surgical site is more clearly displayed; 3) for a precise surgery, subtle tremor may even lead to a failure. The powerful vibration-filtering function of the robot can filter out involuntary vibrations of the human hand, and minimize the amount of bleeding and the RWIT while ensuring tight closure of the wound. Therefore, the defects caused by the intraoperative operation due to the physiological vibration are greatly reduced, which enhances the stability of the operations; and the leverage of the conventional laparoscope is eliminated. Because of the robot, signals from actual operations of a surgery are demagnified into proper movements of the working arms by the reference to the demand in the body cavity; 4) surgical instruments with fine movement, flexibility and stability make the various intracavity operations such as suturing and closure that are difficult for conventional laparoscopic surgery simple and flexible, and can complete various precise and complicated surgeries in a small space; 5) the operations in the robot are accessible to general surgeons and their skills are relatively easy to master. This study found that difference in IOBL between the two groups may be more closely related to robot-assisted laparoscopic surgery. Previous studies have found that robot-assisted laparoscopic surgery can reduce IOBL and shorten hospital stay [16, 17], and the conventional laparoscopic surgery is more difficult to conduct with a prolonged operation time due to the small operation space, which is consistent with the results of this study [18]. In terms of renal warm ischemic time, previous multicenter studies found that robot-assisted laparoscopic surgery can significantly shorten the time compared with an open surgery group or a conventional laparoscopic surgery [19, 20]. Moreover, robot-assisted laparoscopic surgery can easily find deformity of renal artery using CT to prevent renal artery blockage effect from being poor, which is consistent with this study [21].

As for the evaluation of postoperative renal function in this study, serum creatinine and cystatin C were chosen as indicators. Serum creatinine has an irreplaceable role in evaluating renal function, and currently urine volume and serum creatinine are still used for diagnosis in patients with acute renal injury [22, 23]. Serum creatinine for evaluating renal function is limited by factors such as diet and age, and its level only begins to increase when the glomerular filtration rate drops below half [24]. Therefore, cystatin C is also used for renal function evaluation in this study because of its relative stability in the blood. So, cystatin C can reflect changes in glomerular filtration rate. And some studies have found cystatin C is positively correlated with the severity of kidney damage [25]. And studies have found that cystatin C has a sensi-

Table 7. Comparison of decreases of cystatin C levels at post-operation, and at post-operative 6 months, 1 year and 2 years between the two groups

Items	The RALNSS group (N=38)	The LNSS group (N=37)	χ^2/t	P
Difference of cystatin C levels between pre- and post-operation (μmol/L)	0.25±0.31	0.25±0.31	-0.036	0.971
Difference of cystatin C levels between post-operation and post-operative 6 months (μmol/L)	0.07±0.03	0.21±0.08	-9.327	0.000
Difference of cystatin C levels between post-operative 6 months and post-operative 1 year (μmol/L)	0.06±0.03	0.12±0.06	-4.122	0.000
Difference of cystatin C levels between post-operative 1 year and post-operative 2 years (μmol/L)	0.07±0.04	0.12±0.06	-3.263	0.002

Note: RALNSS, robot-assisted laparoscopic nephron-sparing surgery; LNSS, laparoscopic nephron-sparing surgery.

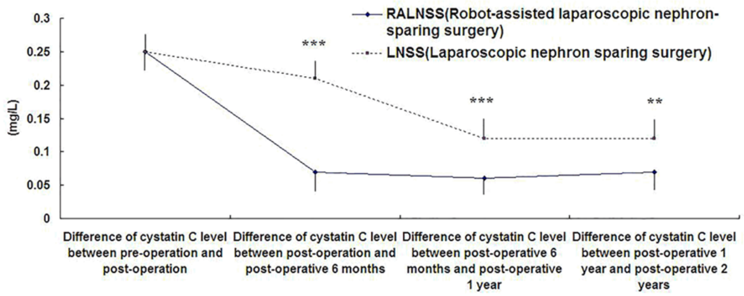

Figure 5. Tendency chart of the decreases of the cystatin C levels at post-operation, and at post-operative 6 months, 1 year and 2 years. **P<0.01; ***P<0.001.

tivity of 70% to the evaluation of renal damage [26]. Robot-assisted laparoscopic surgery is finer than conventional laparoscopic surgery, so it can perform a variety of fine and complex high-precision surgical operations in a small space. For NSS, some relatively complicated tumors with special growth sites can also achieve complete resection under the premise of ensuring safety, and can preserve the nephrons to protect the residual renal function to a maximum extent. This study found that during the 2-year follow-up, the levels of serum creatinine and cystatin C in the RALNSS group were significantly lower than those in the LNSS group, which was closely related to the operations and the preservation of nephrons. There was no significant abnormality in the incidence of complications in the two groups, while some studies have suggested that laparoscopic surgery has a high incidence of complications [27]. The inconsistency may be related to the small sample size in this study. No recurrence was found in either group in this study, while a study in 2016 found that the recurrence rate was 5.6% in patients who underwent nephron-sparing surgery [28]. Small sample size in this study may account for the inconsistency.

The sample size of this study is small, and the size requires expansion for further research. The follow-up time of this study is short, and longer follow-up time on renal function should be put in the research.

In conclusion, RALNSS has shorter warm ischemia time and operation time, and less bleeding as well as better protection for renal function compared to LNSS alone in the treatment of complex renal neoplasms, suggesting that RALNSS for RCC is worthy of promotion and application in clinical practice.

Disclosure of conflict of interest

None.

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References

[1] Casuscelli J, Weinhold N, Gundem G, Wang L, Zabor EC, Drill E, Wang PI, Nanjangud GJ, Redzematovic A, Nargund AM, Manley BJ, Arcila ME, Donin NM, Cheville JC, Thompson RH, Pantuck AJ, Russo P, Cheng EH, Lee W, Tickoo SK, Ostrovnaya I, Creighton CJ, Papaemmanuil E, Seshan VE, Hakimi AA and Hsieh JJ. Genomic landscape and evolution of metastatic chromophobe renal cell carcinoma. JCI Insight 2017; 2.

[2] Jemal A, Siegel R, Xu J and Ward E. Cancer statistics, 2010. CA Cancer J Clin 2010; 60: 277-300.

[3] Chen W, Zheng R, Baade PD, Zhang S, Zeng H, Bray F, Jemal A, Yu XQ and He J. Cancer statistics in China, 2015. CA Cancer J Clin 2016; 66: 115-132.
[4] Pak JS, Lee JJ, Bilal K, Finkelstein M and Palese MA. Utilization trends and outcomes up to 3 months of open, laparoscopic, and robotic partial nephrectomy. J Robot Surg 2017; 11: 223-229.
[5] Caputo PA, Zargar H, Ramirez D, Andrade HS, Akca O, Gao T and Kaouk JH. Cryoablation versus partial nephrectomy for clinical t1b renal tumors: a matched group comparative analysis. Eur Urol 2017; 71: 111-117.
[6] Kalogirou C, Fender H, Muck P, Hey V, Krebs M, Riedmiller H and Vergho D. Long-term outcome of nephron-sparing surgery compared to radical nephrectomy for renal cell carcinoma>/=4 cm - a matched-pair single institution analysis. Urol Int 2017; 98: 138-147.
[7] Lane BR, Fergany AF, Weight CJ and Campbell SC. Renal functional outcomes after partial nephrectomy with extended ischemic intervals are better than after radical nephrectomy. J Urol 2010; 184: 1286-1290.
[8] Serni S, Vittori G, Masieri L, Gacci M, Lapini A, Siena G, Vignolini G, Mari A, Carini M and Minervini A. Robotic vs open simple enucleation for the treatment of T1a-T1b renal cell carcinoma: a single center matched-pair comparison. Urology 2014; 83: 331-337.
[9] Minervini A, Tuccio A, Masieri L, Veneziano D, Vittori G, Siena G, Gacci M, Vignolini G, Mari A, Sebastianelli A, Salvi M, Serni S and Carini M. Endoscopic robot-assisted simple enucleation (ERASE) for clinical T1 renal masses: description of the technique and early postoperative results. Surg Endosc 2015; 29: 1241-1249.
[10] Yu J, Zhang G, Liang P, Yu XL, Cheng ZG, Han ZY, Zhang X, Dong J, Li QY, Mu MJ and Li X. Midterm results of percutaneous microwave ablation under ultrasound guidance versus retroperitoneal laparoscopic radial nephrectomy for small renal cell carcinoma. Abdom Imaging 2015; 40: 3248-3256.
[11] Andrade HS, Zargar H, Caputo PA, Akca O, Kara O, Ramirez D, Haber GP, Stein RJ and Kaouk JH. Five-year oncologic outcomes after transperitoneal robotic partial nephrectomy for renal cell carcinoma. Eur Urol 2016; 69: 1149-1154.
[12] Kutikov A and 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: 844-853.
[13] Klapperich ME, Abel EJ, Ziemlewicz TJ, Best S, Lubner MG, Nakada SY, Hinshaw JL, Brace CL, Lee FT Jr and Wells SA. Effect of tumor complexity and technique on efficacy and complications after percutaneous microwave ablation of stage t1a renal cell carcinoma: a single-center, retrospective study. Radiology 2017; 284: 272-280.
[14] Jang HA, Jin WK, Byun SS, Hong SH, Kim YJ, Park YH, Yang KS, Cho S, Cheon J and Kang SH. Oncologic and functional outcomes after partial nephrectomy versus radical nephrectomy in t1b renal cell carcinoma: a multicenter, matched case-control study in korean patients. Cancer Res Treat 2016; 48: 612-620.
[15] Husain FZ, Badani KK, Sfakianos JP and Mehrazin R. Emerging surgical treatments for renal cell carcinoma. Future Oncol 2016; 12: 921-929.
[16] Kara O, Maurice MJ, Malkoc E, Ramirez D, Nelson RJ, Caputo PA, Stein RJ and Kaouk JH. Comparison of robot-assisted and open partial nephrectomy for completely endophytic renal tumours: a single centre experience. BJU Int 2016; 118: 946-951.
[17] Zhu X, Yang X, Hu X and Zhang X. Retroperitoneoscopic versus open surgical radical nephrectomy for 152 Chinese patients with large renal cell carcinoma in clinical stage cT2 or cT3a: a long-term retrospective comparison. J Cancer Res Ther 2016; 12: 805-810.
[18] Zhang C, Guo F, Wang H, Ye C, Zhang Z, Yang B, Xu C and Sun Y. The application of hem-o-lok clips tied with threads to improve surgical view in retroperitoneal laparoscopic surgery for renal cell carcinoma. J Laparoendosc Adv Surg Tech A 2017; 27: 171-174.
[19] Peyronnet B, Seisen T, Oger E, Vaessen C, Grassano Y, Benoit T, Carrouget J, Pradere B, Khene Z, Giwerc A, Mathieu R, Beauval JB, Nouhaud FX, Bigot P, Doumerc N, Bernhard JC, Mejean A, Patard JJ, Shariat S, Roupret M and Bensalah K. Comparison of 1800 robotic and open partial nephrectomies for renal tumors. Ann Surg Oncol 2016; 23: 4277-4283.
[20] Zargar H, Allaf ME, Bhayani S, Stifelman M, Rogers C, Ball MW, Larson J, Marshall S, Kumar R and Kaouk JH. Trifecta and optimal perioperative outcomes of robotic and laparoscopic partial nephrectomy in surgical treatment of small renal masses: a multi-institutional study. BJU Int 2015; 116: 407-414.
[21] Bauman TM, Potretzke AM, Vetter JM, Bhayani SB and Figenshau RS. Cerebrovascular disease and chronic obstructive pulmonary disease increase risk of complications with robotic partial nephrectomy. J Endourol 2016; 30: 293-299.
[22] Haase M, Bellomo R and Haase-Fielitz A. Serum cystatin C may diagnose rather than predict acute kidney injury. Am J Kidney Dis 2012; 59: 582; author reply 582.

[23] Haase-Fielitz A, Haase M, Bellomo R, Calzavacca P, Spura A, Baraki H, Kutschka I and Albert C. Perioperative hemodynamic instability and fluid overload are associated with increasing acute kidney injury severity and worse outcome after cardiac surgery. Blood Purif 2017; 43: 298-308.
[24] Han WK, Wagener G, Zhu Y, Wang S and Lee HT. Urinary biomarkers in the early detection of acute kidney injury after cardiac surgery. Clin J Am Soc Nephrol 2009; 4: 873-882.
[25] Stevens LA, Coresh J, Schmid CH, Feldman HI, Froissart M, Kusek J, Rossert J, Van Lente F, Bruce RD 3rd, Zhang YL, Greene T and Levey AS. Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. Am J Kidney Dis 2008; 51: 395-406.
[26] Delaney MP, Stevens PE, Al Hasani M, Stowe HJ, Judge C and Lamb EJ. Relationship of serum cystatin C to peritoneal and renal clearance measures in peritoneal dialysis: a cross-sectional study. Am J Kidney Dis 2008; 51: 278-284.
[27] Hadjipavlou M, Khan F, Fowler S, Joyce A, Keeley FX and Sriprasad S. Partial vs radical nephrectomy for t1 renal tumours: an analysis from the british association of urological surgeons nephrectomy audit. BJU Int 2016; 117: 62-71.
[28] Shah PH, Moreira DM, Okhunov Z, Patel VR, Chopra S, Razmaria AA, Alom M, George AK, Yaskiv O, Schwartz MJ, Desai M, Vira MA, Richstone L, Landman J, Shalhav AL, Gill I, Kavoussi LR. Positive surgical margins increase risk of recurrence after partial nephrectomy for high risk renal tumors. J Urol 2016; 196: 327-34.