Surgical and Oncologic Outcomes of Laparoscopic Versus Open Radical Nephrectomy with Venous Thrombectomy: A Propensity-Matched Retrospective Cohort Study

**ABSTRACT**

**Background:** To compare the surgical and oncologic outcomes between laparoscopic and open radical nephrectomy with venous thrombectomy (LRN-VT, ORN-VT) in patients with renal tumor and venous thrombus.

**Materials and Methods:** We conducted a propensity-matched retrospective cohort study of 302 patients with renal tumor and venous thrombus from January 2014 to January 2021. We compared surgical outcomes and we used the Kalan-Meier method to assess the overall survival (OS), tumor-specific survival (TSS), metastasis-free survival (MFS) and local recurrence-free survival (LRFS). The Pearson chi-square test and Fisher exact test, Wilcoxon rank sum test, Cox proportional hazards regression model and log-rank test were used.

**Results:** After 1:1 matching, 94 patients were identified in each group and baseline characteristics were comparable. The LRN-VT group had less operative time (median 292min vs 326min, P < 0.001), less blood loss (median 500 ml vs 1000 ml, P < 0.001), fewer packed red blood cells transfusion (median 800 ml vs 1200 ml, P < 0.001) and less fresh frozen plasma transfusion (median 400 ml vs 600 ml, P < 0.001). The ORN-VT group had higher complication rate (39.4% vs 21.3%, P = 0.007), higher Clavien grade (P = 0.005) and longer postoperative hospital stay (median 10d vs 8d, P < 0.001). The median time to local recurrence were 36mon after a median follow-up of 31mon in the LRN-VT group and 8mon (IQR 6-15 mon) after a median follow-up of 32mon in the ORN-VT group (P = 0.007). The hazard ratio of LRFS for the LRN-VT group was 0.18 (95% CI 0.05–0.62, P = 0.007).

**Conclusions:** LRN-VT can result in favorable surgical outcomes and a better LRFS compared with ORN-VT.

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1. INTRODUCTION

Renal tumors, especially the renal cell carcinoma (RCC), can enlarge from the kidney and involve the venous system. Venous thrombus occurs up to 10% in patients with RCC [1]. Radical nephrectomy and venous thrombectomy (RN-VT) can offer reasonable long-term survival in such patients and the 5-yr disease-specific survival rate can be 53% to 64% [2, 3]. Open surgery remains the preferred treatment option [4]. Nevertheless, several reports have introduced the application and confirmed the feasibility of pure laparoscopy or hand-assisted laparoscopy in RN-VT [5–10]. Until now, less literature reported the comparative analysis between laparoscopic radical nephrectomy with venous thrombectomy (LRN-VT) and open radical nephrectomy with venous thrombectomy (ORN-VT) in patients with renal tumor and venous thrombus.

In this study, we performed a propensity-matched retrospective cohort study to compare the surgical and oncologic outcomes following LRN-VT and ORN-VT in patients with renal tumor and venous thrombus. We hypothesized that LRN-VT could achieve comparable outcomes compared with ORN-VT.

2. MATERIALS AND METHODS

2.1 DATA SOURCE AND STUDY COHORT

We followed the STROBE statement and this study is fully compliant with the STROCSS criteria [11]. Our registration unique identifying number is researchregistry7016.

Following institutional review board approval, we retrospectively reviewed our database (Peking University Third Hospital Thrombus Database, PUTH-TD) containing medical records of all patients with renal vein thrombus or inferior vena cava (IVC) thrombus from January 2014 to January 2021 (n = 350). The database has been constructed prospectively since January 2014. Two full-time clinical data managers had all access to the data through electric case report forms (eCRF) and were responsible for data entry, verification and quality control. The demographic, perioperative, postoperative and follow-up data were accurately recorded. The inclusive criteria were as follows: (1) pathologically confirmed tumor of renal origin; (2) detailed information on surgical procedures; (3) no comorbidity of hemorrhagic disease; (4) minimum follow-up of 6 mon. The patients who were treated by robot-assisted LRN-VT (RALRN-VT) or who didn’t receive surgical treatment were excluded.

2.2 SURGICAL PROCEDURES

The techniques of LRN-VT and ORN-VT at our institution have been described previously [8, 12–14]. For LRN-VT, both transperitoneal approach and retroperitoneal approach were used in our center depending on the thrombus level, tumor side, surgery history and invading the IVC wall or not. For level 0 thrombus, we didn’t block the IVC and we cut off the renal vein from the segment without tumor thrombus. For level I thrombus, the IVC was partially clamped using a Satinsky clamp. We incised the IVC and removed the thrombus and then irrigated the IVC with heparinized saline before suturing. For level II thrombus, we clamped the IVC below the thrombus, the contralateral renal vein and the IVC above the thrombus sequentially after we cut off the renal artery on the tumor side. The contralateral renal artery was blocked for the left tumor, while the left renal artery was not blocked for the right tumor. Segmental resection of the IVC would be considered if the thrombus invaded the IVC wall extensively. If minor involvement of the IVC wall occurred, we performed resection of the invaded vessel wall rather than segmental resection. For level III or IV thrombus, the first porta hepatitis should be blocked and the Foley catheter-assisted six-step thrombectomy technique [12] was used in our center. If the right atrium was involved, ORN-VT is usually needed. We usually incised the thoracoabdominal midline and the “milking” technique is performed to squeeze the intra-atrial thrombus back into the IVC.

2.3 FOLLOW-UP

We provided the same follow-up plan to all patients and follow-up data were regularly collected (symptoms and signs, laboratory tests, imaging examination of the chest,
abdomen and pelvis). The laboratory tests included routine blood test and blood biochemical test. The imaging examination included computed tomography (CT), magnetic resonance imaging (MRI) and X ray. Patients were followed up every 3 mon after surgery in the first year, then 6 mon to the third year, then annually thereafter. We determined the death reason according to the death certificate issued by the local medical institution if a patient died during the interval of follow-up visit or we determined that by the treating physicians.

2.4 OUTCOMES AND DEFINITIONS
Primary outcomes contained surgical outcomes and oncologic outcomes. The surgical outcomes were represented by perioperative and postoperative outcomes (operative time, blood loss and complication rate, et al) between the two groups and the oncologic outcomes were represented by the overall survival (OS), tumor-specific survival (TSS), metastasis-free survival (MFS) and local recurrence-free survival (LRFS). Complications were evaluated within 30 days after surgery. OS meant the length of time from surgery to death from any cause. TSS was defined as the time from surgery to death due to tumor. LRFS was defined as the time from surgery to local recurrence (tumor recurrence in or abutting the previous surgical bed) based on CT or MRI. MFS was defined as the time from surgery to the development of metastatic disease (new lesions in other organs, brain, lung, liver, bone, et al) based on CT or MRI. MFS was only assessed in patients with M0 diseases.

The presence of local symptoms was defined as a palpable mass, pain, gross hematuria. Patients with edema, fever, swelling, fatigue and weight loss, et al were thought to have systemic symptoms. The American Society of Anesthesiologists Physical Status classification system (ASA level) [15] was introduced to estimate the operative risk of patients. Thrombus level was classified using the Mayo Clinic classification of tumor thrombus level [1]. Postoperative complications were graded according to the Clavien-Dindo grading system [16].

The histological diagnosis of renal tumors was based on the World Health Organization (WHO) classification system (2004 and 2016 version) [17, 18]. The Fuhrman system was applied to RCC nuclear grading [19]. A sarcomatoid differentiation was defined as RCC accompanied by histological appearance of spindle-cell sarcoma. The 2017 version of the tumor-node-metastasis (TNM) classification was used for clinical staging based on postoperative pathological specimen.

2.5 DATA QUALITY AND BIAS CONTROL
We designed a precise eCRF containing all the necessary medical information and standardized the definition, naming method and data type of each variable. We set up mandatory fields to reduce data missing and two trained data managers performed data entry to reduce logic errors. The data managers were blinded to the study design. A third party checked the database regularly to keep the authenticity and accuracy.

We set strict criteria for inclusion and exclusion to reduce the selection bias. We performed a propensity-matched comparative analysis to minimize the influence of confounding bias and to identify a cohort of patients with comparable baseline characteristics. The propensity score was estimated by a multivariable logistic regression model and the 1:1 matching without replacement was performed with a caliper width equal to 0.02. Patients were matched regarding age, body mass index (BMI), ASA level, comorbidity, tumor diameter, thrombus level and metastasis at diagnosis. Matching was performed by a researcher who didn’t know the outcomes.

An independent researcher who was blinded to the matched-cohort analyzed the outcomes to control the information bias. Except for the routine review after surgery, the data managers conducted telephone interviews every 3–6 mon and collected the follow-up information to reduce the withdraw bias.

2.6 STATISTICAL ANALYSIS
Baseline characteristics were shown for categorical variables and continuous variables. We reported the medians and interquartile ranges for non-normally distributed continuous variables and the means and standard deviations for normally distributed continuous variables. Categorical variables were reported as frequencies and proportions. The chained multiple imputation was used to resolve the missing data. We compared differences between non-normally distributed continuous data and ordered categorical data with the Wilcoxon sum rank test and compared differences between unordered categorical data with the Chi-square test and Fisher exact test. In the matched cohort, the paired t-test, the Wilcoxon signed rank or the McNemar test was applied to compare differences. We used the Kaplan-Meier method to perform survival analysis and assessed the differences between the propensity-matched groups with log-rank test. Cox proportional hazards regression model was used to estimate the relative oncologic outcomes after adjusting the variables that satisfied the proportional hazards assumptions (thrombus level, lymph node metastasis and distant metastasis, perinephric fat invasion, adjuvant therapy, et al). A hazard ratio (HR) less than 1.0 favored LRN-VT. All statistical tests were performed by SPSS version 25.0 (IBM, Armonk, NY, USA) and the R statistics package version 3.6.1 (R Project for Statistical Computing, www.r-project.org). All tests were two-sided, and the significance level was set at p < 0.05.
3. RESULTS

3.1 PATIENT CHARACTERISTICS

Of consecutive 350 patients identified, 32 patients were excluded for pathologically confirmed tumors that were not renal origin, 6 patients were excluded for RALRN-VT, 6 patients were excluded because of conservative treatment and 4 patients were excluded for shorter than 6 mon of follow-up. 302 patients were matched, including 148 patients treated with LRN-VT and 154 patients treated with ORN-VT. Before propensity matching, significant differences existed in several baseline variables (Table 1). After matching, 94 patients were matched in each group and no significant differences were found in baseline characteristics.

| BEFORE PROPENSITY-MATCHING | AFTER PROPENSITY MATCHING |
|-----------------------------|---------------------------|
| **LRN-VT** (N = 148)       | **ORN-VT** (N = 154)      | **P VALUE**     | **LRN-VT** (N = 94) | **ORN-VT** (N = 94) | **P VALUE**     |
| Age (yr), median (IQR)      | Age (yr), median (IQR)    | <0.001         | Age (yr), median (IQR) | Age (yr), median (IQR) | 0.80           |
| Male                        | Male                      | 0.83           | Male                      | Male                      | 0.28           |
| Female                      | Female                    | 0.73           | Female                    | Female                    | –              |
| BMI (kg/m2), median (IQR)   | BMI (kg/m2), median (IQR) | <0.001         | BMI (kg/m2), median (IQR) | BMI (kg/m2), median (IQR) | 0.29           |
| Laterality (n/%)            | Laterality (n/%)          | 0.22           | Laterality (n/%)          | Laterality (n/%)          | 0.29           |
| Left                        | Left                      | 0.32           | Left                      | Left                      | –              |
| Right                       | Right                     | 0.26           | Right                     | Right                     | 0.32           |
| ASA level (n/%)             | ASA level (n/%)           | <0.001         | ASA level (n/%)           | ASA level (n/%)           | 0.88           |
| Local                       | Local                     | 0.26           | Local                     | Local                     | 0.32           |
| Systemic                    | Systemic                  | 0.69           | Systemic                  | Systemic                  | 0.23           |
| Comorbidity (n/%)           | Comorbidity (n/%)         | 0.004          | Comorbidity (n/%)         | Comorbidity (n/%)         | 0.72           |
| Hypertension                | Hypertension              | 0.004          | Hypertension              | Hypertension              | 0.72           |
| Coronary heart disease      | Coronary heart disease    | 0.004          | Coronary heart disease    | Coronary heart disease    | 0.72           |
| Diabetes mellitus           | Diabetes mellitus         | 0.004          | Diabetes mellitus         | Diabetes mellitus         | 0.72           |
| Cerebrovascular disease     | Cerebrovascular disease   | 0.004          | Cerebrovascular disease   | Cerebrovascular disease   | 0.72           |
| Chronic lung disease        | Chronic lung disease      | 0.004          | Chronic lung disease      | Chronic lung disease      | 0.72           |
| Surgery history             | Surgery history           | 0.004          | Surgery history           | Surgery history           | 0.72           |
| Preoperative targeted therapy (n/%) | Preoperative targeted therapy (n/%) | 0.004          | Preoperative targeted therapy (n/%) | Preoperative targeted therapy (n/%) | 0.72           |
| Tumor diameter (cm), median (IQR) | Tumor diameter (cm), median (IQR) | 0.004          | Tumor diameter (cm), median (IQR) | Tumor diameter (cm), median (IQR) | 0.72           |
| Preoperative SCR (μmol/L), median (IQR) | Preoperative SCR (μmol/L), median (IQR) | 0.004          | Preoperative SCR (μmol/L), median (IQR) | Preoperative SCR (μmol/L), median (IQR) | 0.72           |
| Thrombus level (n/%)        | Thrombus level (n/%)      | <0.001         | Thrombus level (n/%)      | Thrombus level (n/%)      | 0.27           |
| 0                           | 0                         | 0.27           | 0                         | 0                         | –              |
| I                           | I                         | 0.27           | I                         | I                         | –              |
| II                          | II                        | 0.27           | II                        | II                        | –              |
| III                         | III                       | 0.27           | III                       | III                       | –              |

(Contd.)
3.2 SURGICAL OUTCOMES
Surgical outcomes were showed in Table 2. Twenty-four patients (25.5%) in the LRN-VT group converted to open surgery. Forty-one patients (43.6%) received adrenalectomy in the LRN-VT group and 44 patients (46.8%) received adrenalectomy in the ORN-VT group (P = 0.66). Nine patients (9.6%) in the LRN-VT group and 23 patients (24.5%) in the ORN-VT group underwent segmental resection of IVC (P = 0.01). The median operative time of ORN-VT was longer than that of LRN-VT (326 min vs 292 min, P = 0.002). The median blood loss of ORN-VT was significantly greater than that of LRN-VT (1000 ml vs 500 ml, P < 0.001). Sixty-three patients (67%) in the ORN-VT group received intraoperative or postoperative blood transfusion, while only 38 patients (40.4%) in the LRN-VT group needed blood transfusion (P < 0.001). The median packed red blood cells transfusion and fresh frozen plasma transfusion in the ORN-VT group were significantly greater than that of LRN-VT (1200 ml vs 800 ml, 600 ml vs 400 ml, all P < 0.001). The complication rate of ORN-VT was higher than that of LRN-VT (39.4% vs 21.3%, P = 0.007) and the Clavien grade was higher in the ORN-VT group than that in the LRN-VT group (P = 0.005). The median postoperative hospital stay of LRN-VT group was shorter than that of ORN-VT group (8d vs 10d, P < 0.001).

3.3 ONCOLOGIC OUTCOMES
After a median follow-up of 31 mon (IQR 19–44 mon) in the LRN-VT group and 32 mon (IQR 17–40 mon) in the ORN-VT group, 28 deaths occurred in each group (29.8% vs 29.8%, P = 1.0). Twenty-four deaths (25.5%) in the LRN-VT group contributed to tumor and all deaths in the ORN-VT group contributed to tumor. The median time to death in the LRN-VT group and ORN-VT group were 17 mon (IQR 9–26 mon) and 12 mon (IQR 9–20.5 mon), respectively (P = 0.29). Among patients with M0 disease (LRN-VT group, n = 73 vs ORN-VT group, n = 65), 33 patients (45.2%) in the LRN-VT group and 36 patients (55.4%) in the ORN-VT group developed distant metastases (P = 0.23). The most common new metastatic sites were lung (n = 44), bone (n = 24) and liver (n = 18). Local recurrence occurred in 1 patient in the LRN-VT group and 5 patients in the ORN-VT group (P = 0.28). The median time to local recurrence in the LRN-VT group and ORN-VT group were 36 mon and 8 mon (IQR 6–15 mon), respectively (P = 0.007). Table 3 summarized the data on follow-up in each group.

Figure 1 depicted the Kaplan-Meier curves of onologic outcomes. We couldn’t observe a statistically significant difference in either OS (Adjusted HR 0.96, 95%CI 0.67–1.40; P = 0.85), TSS (Adjusted HR 1.03, 95%CI 0.69–1.52; P = 0.90) or MFS (Adjusted HR 0.89, 95%CI 0.58–1.38; P = 0.61) between the two matched groups (Figure 1A, B and C). Patients who underwent LRN-VT had a lower risk of local recurrence compared to patients who underwent ORN-VT (Adjusted HR 0.18, 95% CI 0.05–0.62, P = 0.007) (Figure 1D).

3.4 PATHOLOGICAL OUTCOMES
Table 4 showed the pathological results of the renal tumors between the two groups. We couldn’t observe a statistically significant difference in either T stage (P = 0.16), lymph node metastasis (0.09), perinephric fat invasion (0.39), histological type (P = 0.37), adrenal...
metastasis (0.25), venous wall involvement (0.61), sarcomatoid differentiation (P = 0.49) or Fuhrman grade (P = 0.12) between the two matched groups.

4. DISCUSSION

LRN-VT has been proved to be an effective surgical approach [6, 10, 20–22] despite insufficient high-level medical-evidence support its overwhelming superiority over ORN-VT. Our propensity-matched cohort study favored that LRN-VT had advantages in operative time, blood loss, postoperative hospital stay as well as complications. However, the survival analysis showed that LRN-VT could not result in a better oncologic outcome when comparing OS, TSS and MFS. Our finding indicated that patients in the LRN-VT group had a better LRFS than those in the ORN-VT group.

| LRN-VT(N = 94) | ORN-VT(N = 94) | P VALUE |
|----------------|----------------|---------|
| Surgical approach (n/%) | – | – |
| Transperitoneal | 63 (67.0) | – |
| Retroperitoneal | 25 (26.6) | – |
| Combined | 6 (6.4) | – |
| Open conversion (n/%) | 24 (25.5) | – |
| Adrenalectomy (n/%) | 41 (43.6) | 44 (46.8) | 0.66 |
| Segmental resection of IVC (n/%) | 9 (9.6) | 23 (24.5) | 0.01 |
| Resection of metastatic tumor (n/%) | 2 (2.1) | 0 (0) | 0.50 |
| Operative time (min), median (IQR) | 292 (242–385) | 326 (253–404) | 0.002 |
| Blood loss (ml), median (IQR) | 500 (200–838) | 1000 (400–2050) | <0.001 |
| Blood transfusion(n/%) | 38 (40.4) | 63 (67.0) | <0.001 |
| Packed RBC transfusion (ml), median (IQR) | 800 (400–1600) | 1200 (800–1600) | <0.001 |
| FFP transfusion (ml), median (IQR) | 400 (400–575) | 600 (400–800) | <0.001 |
| Postoperative SCR | 97 (77.5–114.5) | 98 (73.5–116) | 0.87 |
| Complications (n/%) | 20 (21.3) | 37 (39.4) | 0.007 |
| Cardiovascular or cerebrovascular events | 1 (1.1) | 0 (0) | – |
| Pneumonia or pleural effusion | 3 (3.2) | 2 (2.1) | – |
| Kidney insufficiency | 3 (3.2) | 4 (4.3) | – |
| Abdominal cavity infection | 1 (1.1) | 2 (1.9) | – |
| Incision infection | 1 (1.1) | 0 (1.3) | – |
| Deep venous thrombus | 2 (2.1) | 3 (3.2) | – |
| Anemia | 3 (3.2) | 14 (14.9) | – |
| Bowel obstruction | 3 (3.2) | 8 (8.5) | – |
| Lymphatic fistula | 0 (0) | 6 (6.4) | |
| Clavien grade of complications (n/%) | – | 0.005 |
| I | 6 (6.4) | 13 (13.8) | – |
| II | 10 (10.6) | 20 (21.3) | – |
| III | 1 (1.1) | 0 (0) | – |
| IV | 3 (3.2) | 4 (4.3) | – |
| Postoperative hospital stay (d), median (IQR) | 8 (6–10) | 10 (8–13) | <0.001 |

Table 2 Comparison of surgical outcomes of LRN-VT group and ORN-VT group in the matched cohort.

LRN-VT, laparoscopic radical nephrectomy with venous thrombectomy; ORN-VT, open radical nephrectomy with venous thrombectomy; IVT, inferior vena cava; RBC, red blood cells; FFP, fresh frozen plasma; ASA, American Society of Anesthesiologists; IQR, interquartile range; SCR, serum creatinine.
Table 3 Comparison of oncologic outcomes between LRN-VT group and ORN-VT group in the matched cohort.
LRN-VT, laparoscopic radical nephrectomy with venous thrombectomy; ORN-VT, open radical nephrectomy with venous thrombectomy; RCC, renal cell carcinoma; IQR, interquartile range.

Figure 1 Survival analysis in the matched cohort. A. Adjusted OS of patients undergoing LRN-VT and ORN-VT; B. Adjusted TSS of patients undergoing LRN-VT and ORN-VT; C. Adjusted MFS of patients undergoing LRN-VT and ORN-VT; D. Adjusted LRFS of patients undergoing LRN-VT and ORN-VT.
many centers applied laparoscopic technique into IVC thrombectomy. Ioannis et al. [9] evaluated the feasibility of laparoscopic procedure in 4 patients with level I thrombus and found that no intra- or postoperative complications occurred. For level II thrombus, Wang et al. [22] reported the surgical outcomes of laparoscopic procedure in 5 patients and found that 1 patient required intraoperative transfusion and encountered bilateral lower limb deep vein thrombus. Tian et al. [8] once presented our laparoscopic experience in 78 patients with level 0–II thrombus and found that 24 patients (30.8%) needed transfusion and 13 patients (16.7%) had complications. Of the 94 patients in our matched LRN-VT cohort, 38 (40.4%) patients needed transfusion and 20 patients (21.3%) had Clavien I–IV complications. A higher transfusion rate and a higher complication rate were met in our LRN-VT cohort and the following reasons could explain the discrepancy. Firstly, we reported the surgical outcomes of level 0–IV thrombus, including 1 patient with level III thrombus and 3 patients with level IV thrombus. For level IV thrombus, Shao et al. [6] reported the transfusion rate was 80% (4/5) and the Clavien I–II grade complication rate was 80% (4/5). Secondly, 21 patients (22.3%) had pathologically confirmed thrombus involving the venous wall and 9 patients (9.6%) received segmental resection of IVC in our LRN-VT cohort. Lastly, 41 patients (43.6%) underwent adrenalectomy. All the factors made our LRN-VT more extensive and more traumatic and led to a relatively higher transfusion rate and a higher complication rate.

Randomized trials focusing on the comparative outcomes of LRN-VT and ORN-VT have not been reported. Some observational studies analyzed the outcomes of the two procedures. Xu et al. [24] compared the surgical outcomes of laparoscopic versus open procedure directly and found that LRN-VT had shorter operative time, less blood loss, shorter hospital stay and less transfusion than ORN-VT. Our surgical outcomes were consistent with

| T stage (n/%) | LRN-VT (N = 94) | ORN-VT (N = 94) | P VALUE |
|-------------|----------------|----------------|--------|
| pT3a        | 15 (16.0)      | 11 (11.7)      | 0.16   |
| pT3b        | 39 (41.5)      | 36 (38.3)      |        |
| pT3c        | 36 (38.3)      | 42 (44.7)      |        |
| pT4         | 4 (4.3)        | 5 (5.3)        |        |
| Lymph node metastasis (n%) | 54 (51.9) | 60 (63.8) | 0.09   |
| Perinephric fat invasion (n%) | 20 (21.3) | 25 (26.6) | 0.39   |
| Adrenal metastasis (n%) | 2 (2.1) | 5 (5.3) | 0.25   |
| Involving the venous wall (n%) | 21 (22.3) | 24 (25.5) | 0.61   |
| Histology (n%) | 78 (83.9) | 75 (79.8) | 0.37   |
| Clear cell RCC | 9 (9.6) | 15 (16.0) |        |
| Papillary type RCC | 1 (1.1) | 0 (0) |        |
| Chromophobe RCC | 1 (1.1) | 2 (2.1) |        |
| Unclassified RCC | 3 (3.2) | 1 (1.1) |        |
| Ewing's sarcoma | 0 (0) | 1 (1.1) |        |
| Nephroblastoma | 1 (1.1) | 0 (0) |        |
| Angiomyolipoma | 1 (1.1) | 0 (0) |        |
| Squamous cell carcinoma | 1 (1.1) | 0 (0) |        |
| Sarcomatoid differentiation (n%) | 9 (9.6) | 12 (12.8) | 0.49   |
| Fuhrman grade (n%) | 1 (1.1) | 3 (3.2) | 0.12   |
| 2 | 36 (38.3) | 29 (30.9) |        |
| 3 | 32 (34.0) | 38 (40.4) | 0.77   |
| 4 | 20 (21.3) | 22 (23.4) |        |

Table 4 Pathological outcomes of LRN-VT group and ORN-VT group.
LRN-VT, laparoscopic radical nephrectomy with venous thrombectomy; ORN-VT, open radical nephrectomy with venous thrombectomy; RCC, renal cell carcinoma.
However, when it comes to the oncologic outcomes, we surgical trauma and maximize the resection of tumor. confirm the superiority.

outcomes of the three procedures to be conducted to level randomized controlled trials comparing the surgical minimally invasive procedures to patients with renal open surgery. We encouraged attempts to apply the minimally invasive procedures, including RALRN-VT. However, based on the results mentioned, we thought we didn't compare RALRN-VT with either LRN-VT or ORN-VT. In our study, we excluded the perioperative outcomes and similar oncologic outcomes concluded that RALRN-VT can achieve more favorable statistically significant difference in OS. Gu et al. [30] reported that there was no statistically significant difference in OS and recurrence-free survival between robotic procedure and open procedure. However, in our study we found that LRN-VT was associated with a lower risk of local recurrence and the median LRFS was much longer in the LRN-VT group than that in the ORN-VT group. The patient with local recurrence in the LRN-VT group (postoperative 36 mon) had postoperative adjuvant targeted therapy with Sunitinib and Axinitib and only 1 patient with local recurrence (postoperative 17 mon) in the ORN-VT group (median local recurrence time 8 mon) had postoperative adjuvant targeted therapy with Pazopanib. We understand this from two perspectives. On the one hand, postoperative adjuvant targeted agents may help prolong the time from surgery to local recurrence. On the other hand, patients without adjuvant therapy in the LRN-VT group (n = 56) had no local recurrence and patients without adjuvant therapy in the ORN-VT group (n = 49) had 4 cases of local recurrence. This could better reflect the weight of surgery in local recurrence control and LRN-VT had superiority in LRFS over ORN-VT. However, owing to the relatively small number of recurrence events in the two groups, our results should not be taken as suggesting that surgical option determines LRFS. More local recurrence events and longer follow-up are necessary to better compare the LRFS between the two groups.

Our study has strengths that enhance the clinical applicability of the findings. To the best of our knowledge, this study represents the largest propensity-matched comparative analysis of LRN-VT versus ORN-VT. This study provided support to the application of laparoscopic procedure in the treatment of renal tumor with venous thrombus. In addition, we reported for the first time that LRN-VT could result in a better LRFS in such patients. However, this study has some limitations. The first one is its retrospective and non-randomized nature. Despite we matched, unknown confounders might exist and affect the results and then limit the internal validity. A large prospective cohort study or a randomized controlled study is needed to better compare the outcomes between the two surgical approaches. Furthermore, a relatively shorter follow-up time limited the observation of oncologic outcome events, especially for the local recurrence event. This study would definitely benefit from a longer follow-up.
5. CONCLUSIONS

LRN-VT is a reliable and effective procedure in the treatment of renal tumor with venous thrombus, despite open procedure remains the preferred surgical option. LRN-VT has advantages in operative time, blood loss, complications and postoperative hospital stay compared with ORN-VT. As for the oncologic outcomes, LRN-VT is not inferior to ORN-VT with regard to OS, TSS and MFS. LRN-VT can result in a better LRFS than ORN-VT and longer follow-up is needed to further validate the finding.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- Rawdata. Rawdata of the study cohort. DOI: https://doi.org/10.29337/ijsonco.127.s1

ETHICS AND CONSENT

This article does not contain any studies with human participants or animals performed by any of the authors; and it receives ethics approval from Peking University Third Hospital Ethics Committee.

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COMPETING INTERESTS

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property.

AUTHOR CONTRIBUTIONS

Yu Zhang: Study design/Project development/Data analysis/Manuscript writing-original draft
Hai Bi: Manuscript writing-reviewing/Project development/Critical revision
Ye Yan: Manuscript writing-reviewing/Project development/Critical revision
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YiMeng Song: Material support
JingHan Dong: Data collection/Data analysis
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