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Perioperative and oncological outcomes of single position retroperitoneoscopic radical nephroureterectomy for upper urinary tract urothelial carcinoma

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Radical nephroureterectomy (RNU) is the gold standard therapy for patients with upper urinary tract urothelial carcinoma (UTUC). In this study, we compared the effect of two surgical techniques, single-position complete retroperitoneoscopic radical nephroureterectomy (SCRNU) and laparoscopic nephroureterectomy with open bladder cuff excision (LNOBE), on perioperative and long-term oncological outcomes in UTUC patients. We retrospectively collected information on baseline characteristics, clinicopathological characteristics, surgical approaches, perioperative data, and survival outcomes from 174 patients who underwent RNU for UTUC between January 2018 and June 2023 in our center. The data were analyzed using the Mann-Whitney test, Fisher's exact test, Chi-square test. Linear regressions were applied to explore the effect of surgery approach on the continuous outcomes. Log-rank test and Kaplan-Meier survival curves were plotted to describe the survival outcome. Univariate and Multivariate Cox regressions were conducted to explore the independent prognostic factors. To address potential selection bias, we also employed an Inverse Probability of Treatment Weighting (IPTW) strategy. Patients who underwent SCRNU had shorter operative times ($p < 0.001$), reduced estimated blood loss ($p < 0.001$), less drainage on the first postoperative day ($p = 0.009$), shorter hospital stays ($p = 0.001$), and better intravesical recurrence-free survival than those who underwent LNOBE (IVRFS, HR: 0.17, 95% CI: 0.07–0.44, $p = 0.007$). Moreover, SCRNU was confirmed to be a protective factor for IVRFS after IPTW-adjusted Cox regression analysis was performed (HR: 0.17, 95% CI: 0.04–0.77, $p = 0.021$). SCRNU not only avoids intraoperative repositioning but also improves perioperative outcomes, including the reduction of operative time, blood loss, and length of hospital stay, and is associated with better IVRFS.

Keywords Upper urinary tract urothelial carcinoma, Radical nephroureterectomy, Single-position, Perioperative outcomes, Intravesical recurrence-free survival

Upper urinary tract urothelial carcinoma (UTUC), which is localized to the renal pelvis and ureter, represents approximately 5–10% of urothelial carcinomas (UCs) and is more prevalent in the Chinese population (20–30%), with a male/female ratio of approximately 2:1. Approximately two-thirds of these patients have advanced to invasive disease at the time of initial diagnosis[1,2]. For localized UTUC patients at high risk, open radical nephroureterectomy (RNU), in combination with bladder cuff excision, is generally used as the principal treatment standard[2,3]. As surgical techniques continue to evolve, open RUN has been replaced by minimally

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invasive laparoscopy RUN because it provides better surgical visibility, lower surgical trauma, and fewer complications[4].

Many different approaches and surgical methods are available for this type of operation. The methods for nephrectomy have been extensively studied and developed, and the most widely used method for treating the inner part of the ureter and bladder wall is open bladder sleeve resection. The drawbacks of traditional LNOBE include the unavoidable need to switch between two positions– from the lateral to the supine position– during surgery and the lower-abdominal large midline incision performed for bladder cuff excision. Single-position complete retroperitoneoscopic radical nephroureterectomy (SCRNU), described by Shi et al., avoids repositioning and an additional lower-abdominal incision[4]. Since 2018, we have also started to use SCRNU to reduce surgical trauma and enhance recovery in patients. In this study, we compared the long-term perioperative and oncological outcomes between SCRNU and traditional LNOBE for UTUC patients.

Materials and methods

Patient selection

We retrospectively enrolled 174 consecutive patients who underwent RNU for UTUC between January 2018 and June 2023 at our centre. Patients who had received or were scheduled to receive neoadjuvant chemotherapy were excluded to ensure a uniform patient population that underwent RNU as the primary treatment. Additionally, those presenting with distant metastases beyond regional lymph nodes or with a history of bladder cancer or contralateral UTUC were also excluded. Among the included patients, 86 received SCRNU, whereas the other 88 patients underwent LNOBE. All enrolled patients underwent preoperative routine urological colour ultrasound and computed tomography urography (CTU) or magnetic resonance urinary tract imaging (MRU) to determine the tumour location and size; additionally, chest CT scanning was performed to exclude patients with lung metastasis. Preoperative cystoscopy was performed to exclude patients with coexisting bladder tumours. Postoperative pathological examinations were conducted to confirm urothelial tumours, and the surgeries were completed by the same surgeon. The baseline characteristics included age at surgery for UTUC, sex (male and female), body mass index (BMI, kg/m^2), comorbidity of hypertension and diabetes, American Society of Anaesthesiologists (ASA) score, preoperative GFR ($mL/min/1.73\ m^2$), and preoperative Cr levels (μmol/L). The clinicopathological characteristics included pathological stage (pT stage) and clinical lymph node stage (cN stage) classified using the 2016 WHO Classification[5], lymphovascular invasion (LVI), concomitant carcinoma in situ (CIS), tumour laterality (right and left), tumour location (renal pelvis, ureter, or both), tumour multifocality, tumour size (in mm), and acceptance of postoperative intravesical chemotherapy and adjuvant chemotherapy. The surgical approaches included SCRNU and LNOBE, which were selected on the basis of the preference of the patients and surgeons and the operating technique. All characteristics and parameters were previously described by Shi et al.[4]. The perioperative data included operative time (in minutes), estimated blood loss for surgery (in mL), intraoperative or postoperative transfusion, postoperative drainage volume, postoperative farting time, length of hospital stay (in days), and length of hospital stay after surgery (in days). This study was approved by the Ethics Committee of the Second Affiliated Hospital of Dalian Medical University, and all methods were conducted in accordance with relevant guidelines and regulations, including the Declaration of Helsinki. Informed consent was obtained from all participants.

Operating technique

SCRNU

After general anaesthesia and endotracheal intubation were performed, a urinary catheter was inserted into the patent and maintained during the procedure. The patient was positioned in a 90° lateral decubitus position on the healthy side in a jackknife posture; care was taken to maintain sufficient separation between the costal margin and iliac crest to establish the surgical channels. The Trocar distribution is illustrated in Fig. 1. Observation port A was located at the intersection of the midaxillary line and a horizontal line 2 cm above the iliac crest. Operation port B was located at the intersection of the anterior axillary line and 1–2 cm below the 12th rib. Operation port C was located at the intersection of the posterior axillary line and 1–2 cm below the 12th rib. Observation port D was located at the intersection of the line connecting ports B and C with the lateral edge of the rectus abdominis. Operation port E was located at the intersection of the lateral edge of the rectus abdominis and the horizontal line of the iliac crest. During the establishment of the trocar channels, care was taken to avoid injury to the peritoneum. A routine radical nephrectomy was performed proximally. After the kidney was fully mobilized and the renal artery and vein were addressed, the laparoscope was inserted through observation port D to shift the visual field towards the pelvic cavity. The ureter was mobilized to its distal end, and a Hem-o-lock clip was placed at the distal ureter near the tumour to prevent urine leakage. The ureter was pulled upwards, forming a funnel-shaped structure at the ureterovesical junction. An ultrasonic scalpel was used to perform sleeve resection of the bladder tissue, and the bladder was sutured using barbed sutures.

LNOBE

After general anesthesia and endotracheal intubation were performed, a urinary catheter was inserted, and the patient was placed in a 90° lateral decubitus position. The detailed surgical steps have been described in another study[6]. The kidney was fully mobilized, and the renal artery and vein were clipped using Hem-o-locks. The ureter was identified at the level of the lower pole of the kidney and then further dissected downwards to the iliac fossa, where it was also clipped with Hem-o-locks. Sleeve resection of the distal ureter and bladder was performed. Then, the patient was repositioned in the supine position. A midline incision was made in the lower abdomen, and the ureter was dissected extraperitoneal to its junction with the bladder. Sleeve resection of the bladder was conducted, followed by bladder closure using barbed sutures.

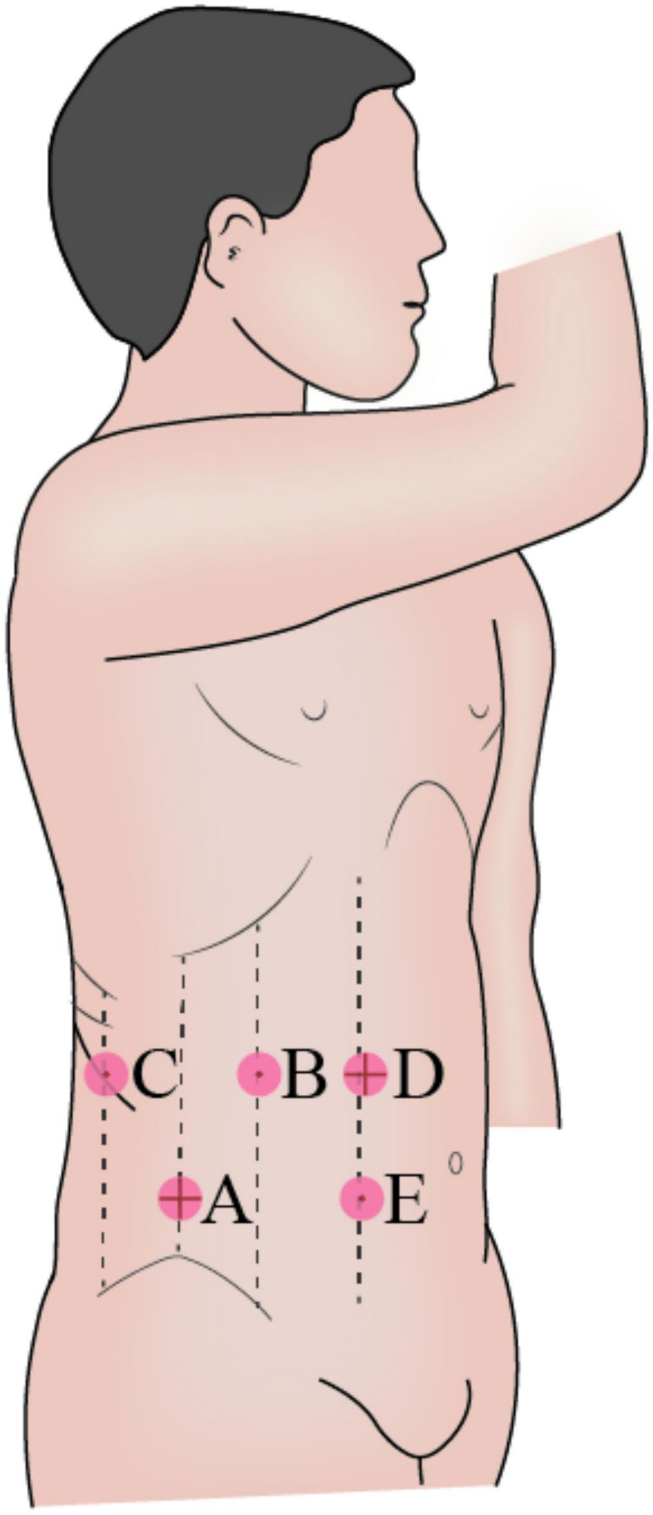

Fig. 1. Port A is located at the intersection of the midaxillary line and a horizontal line 2 cm above the iliac crest; Port B is located at the intersection of the anterior axillary line and 1–2 cm below the 12th rib; Port C is located at the intersection of the posterior axillary line and 1–2 cm below the 12th rib; Port D is located at the intersection of the line connecting ports B and C with the lateral edge of the rectus abdominis; Port E is located at the intersection of the lateral edge of the rectus abdominis and the horizontal line of the iliac crest.

Follow-up

All patients were administered intravesical chemotherapy within 24 h after the operation, with gemcitabine being the drug of choice. The drainage tube in the area of the operation was removed once the drainage volume was less than 50 mL within 24 h, and follow-up abdominal and pelvic CT scans revealed no significant abnormalities. Follow-up examinations, including symptom records, physical examination, cytology, computed tomography for chest and urography, and cystoscopy, were performed every three months in the first two years after RNU, every six months within 5 years, and then yearly thereafter.

Outcomes

Perioperative outcomes

Operative time was defined as the duration (in minutes) from the initial incision to the completion of the surgical procedure. The estimated blood loss (EBL) was the total volume of blood lost during the surgery, which was calculated on the basis of the suction volumes and surgical sponges as recorded in the anaesthesia logs. Drainage on the first postoperative day was the total fluid output (in milliliters) collected from the drainage system on the first postoperative day. The drainage fluid was generally serous or mildly bloody, reflecting normal postoperative exudation and minor bleeding. The length of hospital stay was defined as the total number of days from the date of surgery to the date of discharge. The recovery of bowel function was defined as the interval (in hours) from the completion of surgery to the first anal passage of flatus, indicating the resumption of gastrointestinal motility. Patients were categorized into two groups on the basis of whether symptoms occurred within 48 h or after 48 h. Perioperative complications, including any events occurring within 30 days postoperatively, were systematically recorded and classified using the Clavien–Dindo grading system.

Survival outcomes

Survival outcomes included recurrence-free survival (RFS), IVRFS, extravesical RFS, overall survival (OS) and cancer-specific survival (CSS). RFS was calculated as the interval from the time of RNU to the time of recurrence at all sites. IVRFS was calculated as the interval from the time of RNU to the time of bladder tumour recurrence, whereas extravesical RFS was defined as the time between RNU and recurrence, with the exception of bladder tumours. OS was defined as the time between surgery and death or the last follow-up. CSS was calculated as the period between surgery and death from the disease or the last follow-up.

Statistical analysis

The Shapiro–Wilk test was conducted to determine whether continuous variables followed a normal distribution. Continuous variables are presented as medians and interquartile ranges (IQRs). We conducted Mann–Whitney tests to compare the differences between the groups because the data did not follow a normal distribution. Categorical variables are presented as frequencies and percentages, and differences between the groups were determined using Fisher's exact test or the chi-square test. All the statistical analyses were conducted using SPSS 26.0. A log-rank test was performed to assess the effect of the surgical approach on patient prognosis, including RFS, IVRFS, extravesical RFS, and OS; the results are presented as hazard ratios (HRs) and 95% confidence intervals (CIs). Kaplan–Meier (KM) survival curves and log-rank tests were performed using R 4.3.2. Univariate and multivariate Cox regression analyses were performed to calculate hazard ratios (HRs) and 95% confidence intervals (CIs), and factors that were significant in the univariate analysis and the previously detected associated-factors were included in the multivariate analysis. Inverse probability of treatment weighting (IPTW) uses standardized methods to control and minimize potential biases such as differences between baseline characteristics of the two groups and confounding effects on survival analyses by assigning appropriate weights to each observation through propensity score values. Cox regression analysis was subsequently performed to confirm the independent factors after IPTW. All the results were considered statistically significant at $p < 0.05$.

Results

Baseline and clinicopathological characteristics

Among the 174 UTUC patients, 86 patients underwent SCRNU, and 88 patients underwent LNOBE. As presented in Table 1, the demographic and clinicopathological characteristics of the SCRNU and LNOBE patients were similar ($p > 0.05$).

Perioperative outcomes

Perioperative metrics

Patients in the SCRNU group had significantly shorter operative times (167.50 min [IQR: 140.75–220.75] vs. 192.50 min [IQR: 169.50–250.00], $p < 0.001$) compared with those in the LNOBE group, as confirmed by linear regression ($\beta = -33.07$, $R^2 = 0.07$, $p < 0.001$; Fig. S1). The estimated blood loss was also lower among SCRNU patients (50.0 mL [IQR: 50.0–105.0] vs. 100.0 mL [IQR: 50.0–200.0], $p < 0.001$), as supported by regression analysis ($\beta = -67.76$, $R^2 = 0.07$, $p < 0.001$; Fig. S2). In addition, postoperative drainage on the first day was significantly reduced in the SCRNU group (91.50 mL [IQR: 50.0–152.5] vs. 125.50 mL [IQR: 85.25–198.25], $p = 0.009$), suggesting diminished tissue exudation and better haemostasis ($\beta = -50.74$, $R^2 = 0.03$, $p = 0.031$; Fig. S3). To further assess blood loss, we evaluated haemoglobin (Hb) levels before and after surgery as an additional index. Although the median reduction in Hb was lower in the SCRNU group (16.00 g/L [IQR: 9.75–23.00]) than in the LNOBE group (20.00 g/L [IQR: 10.00–25.00]), linear regression adjusted for potential confounders did not reveal a statistically significant difference ($\beta = -2.783$, $R^2 = 0.01$, $p = 0.135$, Fig. S4). Moreover, the total hospital stay (11.00 days [IQR: 9.00–14.00] vs. 13.00 days [IQR: 11.00–17.75], $p = 0.001$) and postoperative hospital stay (6.00 days [IQR: 5.00–6.00] vs. 7.00 days [IQR: 5.00–8.00], $p < 0.001$) were notably shorter in the SCRNU group,

	SCRNU ($n=86$)	LNOBE ($n=88$)	*P* value
Demographic characteristics			
Age (years)	69 (64–75)	70 (63–77)	0.081
Gender, n (%)			
Male	44 (51.2%)	48 (54.5%)	0.655
Female	42 (48.8%)	40 (45.5%)	
BMI (kg/m^2)	23.99 (22.16–26.88)	24.40 (22.9-26.53)	0.324
Hypertension			
No	46 (53.5%)	46 (52.3%)	0.872
Yes	40 (46.5%)	42 (47.7%)	
Diabetes			
No	64 (74.4%)	61 (69.3%)	0.455
Yes	22 (25.6%)	27 (30.7%)	
ASA score, n (%)			
≤2	12 (14.0%)	13 (14.8%)	0.878
≥3	74 (86.0%)	75 (85.2%)	
Pre-operative GFR (ml/min/1.73 m^2)	73.26 (59.98–86.96)	75.45 (58.87–89.84)	0.642
Pre-operative Cr (μmol/l)	90.36 (70.89-106.51)	86.23 (70.40-105.37)	0.833
Clinical and pathological characteristics			
pT stage, n (%)			
T a, T1	19 (22.1%)	16 (18.2%)	0.092
T2	35 (40.7%)	24 (27.3%)	
T3	28 (32.6%)	45 (51.1%)	
T4	4 (4.7%)	3 (3.4%)	
cN stage, n (%)			
N0	85 (98.8%)	88 (100%)	0.991
N+	1 (1.2%)	0 (0%)	
LVI, n (%)			
No	57 (66.3%)	62 (70.5%)	0.554
Yes	29 (33.7%)	26 (29.5%)	
CIS, n (%)			
No	83 (96.5%)	86 (97.7%)	0.979
Yes	3 (3.5%)	2 (2.3%)	
Laterality, n (%)			
Right	43 (50.0%)	39 (44.3%)	0.453
Left	43 (50.0%)	49 (55.7%)	
Location, n (%)			
Renal pelvis	40 (46.5%)	38 (43.2%)	0.426
Ureter	41 (47.7%)	40 (45.5%)	
Both	5 (5.8%)	10 (11.4%)	
Tumor multifocality, n (%)			
No	79 (91.9%)	76 (86.4%)	0.245
Yes	7 (8.1%)	12 (13.6%)	
Tumor size (mm)	24.50 (17.00–34.00)	27.00 (17.00–40.00)	0.255
Post-operative intravesical chemotherapy, n (%)			
No	27 (31.4%)	27 (30.7%)	0.919
Yes	59 (68.6%)	61 (69.3%)	
Adjuvant chemotherapy, n (%)			
No	54 (62.8%)	55 (62.5%)	0.968
Yes	32 (37.2%)	33 (37.5%)	

Table 1. Patient demographic, clinical and pathological characteristics. Continuous variables are presented as medians (IQRs: Q1–Q3), where IQR represents the interquartile range (from the 1st quartile to the 3rd quartile). Categorical variables are presented as numbers (percentages), where percentages are calculated based on the total number of patients in each group. Significant values are in bold.

a finding further confirmed by linear regression (β = −2.433, R^2 = 0.05, $p < 0.001$, Fig. S5; β = −1.819, R^2 = 0.04, $p < 0.001$, Fig. S6, respectively). These perioperative outcomes are summarized in Table 2.

Postoperative complications

Postoperative complications were systematically recorded and classified according to the Clavien–Dindo classification system. The overall incidence of complications did not differ significantly between the two groups, occurring in 11 patients (12.8%) in the SCRNU group and 11 patients (12.5%) in the LNOBE group ($p = 1.000$). Specifically, Clavien–Dindo Grade I complications were noted in 6 (7.0%) SCRNU patients versus 4 (4.5%) LNOBE patients ($p = 0.64$), whereas Grade II complications occurred in 5 (5.8%) SCRNU patients versus 7 (8.0%) LNOBE patients ($p = 0.68$). No patients in either group experienced Grade III–V complications. Urinary leakage, classified as a Clavien–Dindo grade II complication, occurred in 2 patients (2.3%) in the SCRNU group and 3 patients (3.4%) in the LNOBE group ($p = 0.79$). Postoperative pelvic CT scans on Day 3 revealed reduced leakage and improved conditions in all patients. Conservative management, including prolonged catheterization, was effective, and all urinary catheters were successfully removed by postoperative Day 7.

Prognosis based on the surgical approach

Kaplan-Meier survival cures and log-rank test

The K-M survival curves are presented in Fig. 2. The surgery approach was not associated with RFS which did not reach statistical significance (HR: 0.60, 95% CI 0.33–1.07; $p = 0.092$). After conducting a subanalysis, we investigated the importance of the protective effect of the surgical approach of SCRNU on IVRFS (HR: 0.17, 95% CI 0.04–0.73, $p = 0.007$). However, the results of the analyses of extravesical RFS (HR: 1.04, 95% CI 0.50–2.29, $p = 0.912$), OS (HR: 1.20, 95% CI 0.56–2.57, $p = 0.615$) and CSS (HR: 1.25, 95% CI 0.45–3.49, $p = 0.665$) were not statistically significant.

Univariate and multivariate Cox analysis for the independent factors of prognosis

To further investigate the factors influencing IVRFS, we conducted univariate and multivariate Cox regression analyses (Table 3). In the univariate analysis, the surgical approach emerged as a significant predictor, with patients who underwent SCRNU demonstrating a markedly reduced risk of intravesical recurrence compared with those who received LNOBE (HR: 0.17, 95% CI: 0.04–0.73, $p = 0.017$). In the subsequent multivariate Cox analysis, the SCRNU surgery approach also was a protective factor for IVRFS (HR: 0.11, 95% CI: 0.02–0.66, $p = 0.016$). We also conducted univariate and multivariate Cox analyses of OS, CSS, RFS and extravesical RFS to explore the prognostic factors, and the detailed results are presented in Supplementary Tables 1–4. In the subgroup analysis of the 120 patients who received postoperative intravesical chemotherapy, we confirmed that

Operative outcomes	SCRNU	LNOBE	*P* value
Operative time (min)	167.50 (140.75–220.75)	192.50 (169.50–250.00)	**< 0.001**
Estimated blood loss (ml)	50.00 (50.00–105.00)	100.00 (50.00–200.00)	**< 0.001**
Intraoperative blood transfusion, n (%)			
No	86 (100.0%)	86 (97.7%)	0.497
Yes	0 (0.0%)	2 (2.3%)	
Drainage on the first postoperative day (ml)	91.50 (50.00–152.50)	125.50 (85.25–198.25)	**0.009**
The decrease value of hemoglobin after surgery	16.00 (9.75–23.00)	20.00 (10.00–25.00)	0.208
Postoperative exhaust			
Within 48 h	64 (74.4%)	61 (69.3%)	0.502
Exceed 48 h	22 (25.6%)	27 (30.7%)	
Length of hospital stay (days)	11.00 (9.00–14.00)	13.00 (11.00–17.75)	**0.001**
Length of hospital stay after surgery (days)	6.00 (5.00–6.00)	7.00 (5.00–8.00)	**< 0.001**
Postoperative complications Clavien-Dindo classification			
Grade 0, n (%)	75 (87.2%)	77 (87.5%)	0.97
Grade I, n (%)	6 (7.0%)	4 (4.5%)	0.64
Grade II, n (%)	5 (5.8%)	7 (8.0%)	0.68
Grade III-V, n (%)	0	0	
Postoperative complications			
Fever, n (%)	6 (7.0%)	9 (10.2%)	0.54
Hemorrhage leading to anemia, n (%)	2 (2.3%)	4 (4.5%)	0.56
Deep vein thrombosis, n (%)	3 (3.5%)	3 (3.4%)	0.84
Urinary leakage, n (%)	2 (2.3%)	3 (3.4%)	0.79

Table 2. Perioperative outcomes of the single-position complete retroperitoneoscopic radical nephroureterectomy (SCRNU) and laparoscopic nephroureterectomy with open bladder cuff excision (LNOBE) patients. Continuous variables are presented as medians (IQRs: Q1–Q3), where IQR represents the interquartile range (from the 1st quartile to the 3rd quartile). Categorical variables are presented as numbers (percentages), where percentages are calculated based on the total number of patients in each group.

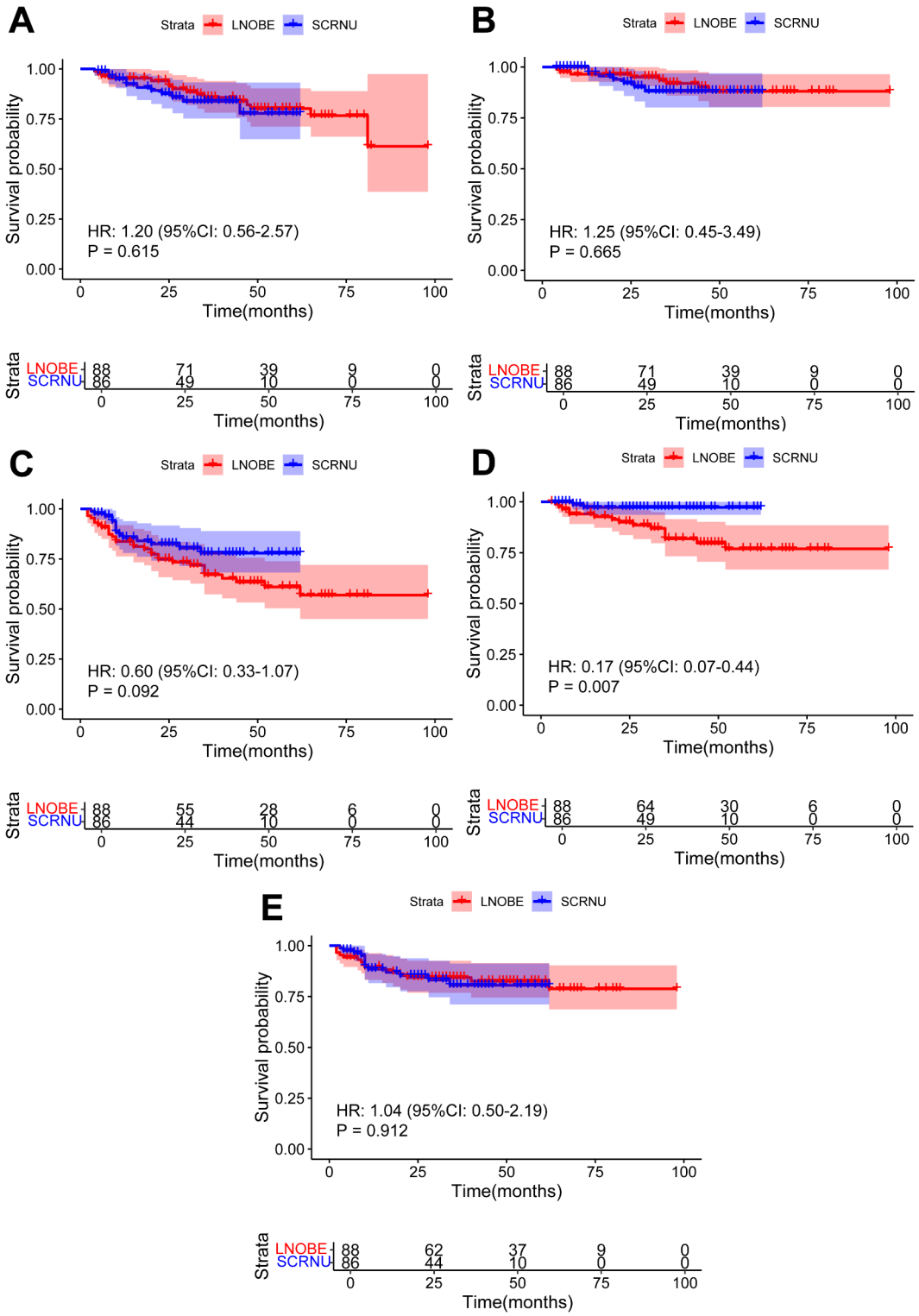

Fig. 2. Kaplan-Meier survival curves for survival outcomes following radical nephroureterectomy, comparing single-position complete retroperitoneoscopic radical nephroureterectomy (SCRNU) and laparoscopic nephroureterectomy with open bladder cuff excision (LNOBE) patients. The survival outcomes are shown as follows: (**A**) overall survival (OS), (**B**) cancer-specific survival (CSS), (**C**) recurrence-free survival (RFS), (**D**) intravesical recurrence-free survival (IVRFS), and (**E**) extravesical recurrence-free survival.

	Univariate		Multivariate	
	Hazard ratio (95% CI)	*p* value	Hazard ratio (95% CI)	*p* value
Age at surgery (years)				
< 69 (ref)	1		1	
≥ 69	0.41(0.14–1.16)	0.093	0.12(0.02–0.61)	**0.010**
Gender				
Female (ref)	1		1	
Male	0.80(0.31–2.07)	0.641	0.31(0.08–1.20)	0.090
BMI				
< 24(ref)	1		1	
≥24	1.91(0.67–5.44)	0.222	1.76(0.41–7.57)	0.449
Hypertension				
No(ref)	1		1	
Yes	1.13(0.43–2.92)	0.806	0.84(0.22–3.17)	0.799
Diabetes				
No(ref)	1		1	
Yes	2.70(1.04-7.00)	**0.042**	7.41(1.59–34.52)	**0.011**
ASA score				
≤ 2(ref)	1		1	
≥3	3.18(0.42–23.97)	0.262	8.34(0.72–96.38)	0.089
Surgery approach				
LNOBE(ref)	1		1	
SCRNU	0.17(0.04–0.73)	**0.017**	0.11(0.02–0.66)	**0.016**
Pre-operative GFR				
< 60(ref)	1		1	
≥60	1.54(0.44–5.36)	0.497	6.98(1.23–39.65)	**0.028**
Pre-operative Cr				
< 133 (ref)	1		1	
≥133	0.87(0.12–6.60)	0.896	11.93(0.61-232.94)	0.102
pT stage				
Ta/T1 (ref)	1		1	
T2	5.84(0.73–46.77)	0.097	37.80(2.03-702.83)	**0.015**
T3	3.94(0.49–31.50)	0.196	12.15(0.77-192.36)	0.076
T4	NA	0.998	NA	0.999
cN stage				
N0 (ref)	1		1	
N+	NA	0.998	NA	1.000
LVI				
No (ref)	1		1	
Yes	0.49(0.14–1.69)	0.256	0.44(0.08–2.39)	0.345
CIS				
No (ref)	1		1	
Yes	2.40(0.32–18.14)	0.395	3.54(0.09-143.87)	0.503
Laterality				
Left (ref)	1		1	
Right	0.71(0.26–1.91)	0.494	0.55(0.12–2.50)	0.440
Location				
Renal pelvis (ref)	1		1	
Ureter	0.64(0.23–1.79)	0.393	0.62(0.11–3.58)	0.595
Both	1.13(0.24–5.24)	0.874	NA	0.998
Tumor multifocality				
No (ref)	1		1	
Yes	1.04(0.24–4.53)	0.963	NA	0.998
Tumor size				
< 25 mm (ref)	1		1	
≥ 25 mm	1.43(0.54–3.75)	0.471	2.45(0.48–12.57)	0.285
Post-operative intravesical chemotherapy				
Continued				

	Univariate		Multivariate	
	Hazard ratio (95% CI)	*p* value	Hazard ratio (95% CI)	*p* value
No (ref)	1		1	
Yes	1.83(0.53–6.38)	0.342	1.09(0.23–5.10)	0.910
Adjuvant chemotherapy				
No (ref)	1		1	
Yes	1.13(0.43–2.97)	0.805	1.10(0.23–5.19)	0.901

Table 3. Univariate and multivariate Cox regression analysis of independent factors for intravesical recurrence-free survival. Significant values are in bold.

the surgical approach was a significant prognostic factor in the univariate Cox regression analysis (HR: 0.19, 95% CI: 0.04–0.86, $p = 0.031$) and multivariate Cox regression (HR: 0.15, 95% CI: 0.03–0.91, $p = 0.040$). The detailed results are presented in Table 4.

IPTW-adjusted Cox regression analysis

Given the significant association between the surgical approach and IVRFS identified in the univariate and multivariate models, we employed an IPTW strategy to address potential selection bias. Sex, age, BMI, hypertension, diabetes status, ASA score, preoperative GFR, preoperative Cr, pT stage, cN stage, LVI, CIS, laterality, location, tumour size, postoperative intravesical chemotherapy and adjuvant chemotherapy were used to generate weighted cohorts, followed by Cox regression analysis. As shown in Table 5, the unadjusted results indicated a markedly lower risk of intravesical recurrence in the SCRNU group than in the LNOBE group (HR: 0.17, 95% CI 0.04–0.73; $p = 0.017$). After IPTW adjustment, SCRNU continued to be an independent predictor of improved IVRFS (HR: 0.17, 95% CI 0.04–0.77, $p = 0.021$), reinforcing the robustness of the association. In contrast, no significant differences emerged between SCRNU and LNOBE in OS, CSS, RFS, or extravesical RFS following IPTW adjustment.

Discussion

The enhanced recovery after surgery (ERAS) protocol aims to reduce postoperative complications and promote early patient recovery[7]. Laparoscopic RNU is widely performed to treat UTUC because of its safe, reproducible, and minimally invasive characteristics[8–10]. Several methods are available for managing the distal ureter during the LNU technique, including open excision[11], transurethral resection[12], and laparoscopic stapling[13]. However, there is no consensus on the best approach to the distal ureter and bladder cuff, and the standard LNU technique is still under development. Compared with open excision, surgery in a single position is more favorable for remitting repositioning, resterilizing, and extending surgical incisions, which is a topic of considerable research interest. Similar to that reported by Xiao et al.[6] and Shi et al.[4], the patients in our study who underwent SCRNU presented better perioperative outcomes, including less blood loss, shorter operative time, less drainage on the first postoperative day, and shorter length of hospital stay, all of which are consistent with the principles of ERAS. However, a formal ERAS protocol was not fully implemented in this study. Instead, certain ERAS-inspired practices, such as early oral intake and early mobilization, are routinely applied to all patients to optimize recovery.

The identification of prognosis-related factors is the cornerstone of high-risk patient identification and cancer management. We observed a significant advantage in IVRFS ($p = 0.016$) for the SCRNU group compared with the LNOBE group. In contrast to the results obtained by Xiao et al.[6] and Shi et al.[4], our findings suggested that SCRNU may reduce the risk of postoperative IVR in UTUC patients. This finding diverges slightly from the prevailing consensus in the literature, where most studies have reported comparable IVR rates across different surgical approaches. However, modified techniques, such as early clipping of the distal ureter, have demonstrated a protective effect against IVR by limiting tumor cell migration during surgery[14]. Several procedural characteristics inherent to SCRNU, including the single position approach, retroperitoneal bladder cuff excision, early ureteral clipping, and reduced ureteral manipulation, may collectively contribute to the improved IVRFS observed in our study. However, these results should be interpreted with caution because variations in surgical techniques, perioperative protocols, and surgeon preferences at a single center may have influenced the outcomes. This underscores the need for future large scale multicenter prospective studies to generate more generalizable evidence and to further clarify the relationship between surgical approach and IVR.

Single postoperative intravesical chemotherapy after RNU to reduce the risk of IVR is supported by level 1 evidence[15]. A meta-analysis by Moretto et al. also revealed that postoperative intravesical chemotherapy significantly reduces intravesical recurrence rates, regardless of whether multiple or single intravesical chemotherapies are used[16]. However, our study did not demonstrate the efficacy of postoperative intravesical chemotherapy for preventing IVR potentially due to limitations in sample size. Recent research has demonstrated that preoperative intravesical instillation of mitomycin C significantly reduces IVR risk[17], which may encourage the development of new protocols for the diagnosis and treatment of UTUC patients. Postoperative adjuvant chemotherapy can improve the OS and PFS of UTUC patients, which was also verified in our study; however, its role in preventing IVRFS has not been fully determined[18–20]. Research by Chung et al. revealed that adjuvant chemotherapy may help improve IVRFS[21]. A meta-analysis of adjuvant chemotherapy for IVR, which included

	Univariate		Multivariate	
	Hazard ratio (95% CI)	*p* value	Hazard ratio (95% CI)	*p* value
Age at surgery (years)				
< 69 (ref)	1		1	
≥ 69	0.45(0.14–1.45)	0.181	0.17(0.03–0.88)	**0.034**
Gender				
Female (ref)	1		1	
Male	0.66(0.23–1.90)	0.442	0.50(0.11–2.19)	0.355
BMI				
< 24 (ref)	1		1	
≥ 24	1.71(0.57–5.09)	0.339	1.07(0.25–4.65)	0.927
Hypertension				
No (ref)	1		1	
Yes	1.47(0.52–4.19)	0.471	1.61(0.32–7.99)	0.560
Diabetes				
No (ref)	1		1	
Yes	3.05(1.07–8.69)	**0.037**	4.04(0.81–20.23)	0.089
ASA score				
≤ 2(ref)	1			
≥ 3	2.84(0.37–21.70)	0.315	7.73(0.55–109.40)	0.130
Surgery approach				
LNOBE(ref)	1		1	
SCRNU	0.19(0.04–0.86)	**0.031**	0.15(0.03–0.91)	**0.040**
Pre-operative GFR				
< 60(ref)	1		1	
≥ 60	1.28(0.36–4.60)	0.702	4.02(0.72–22.55)	0.113
Pre-operative Cr				
< 133 (ref)	1		1	
≥133	0.95(0.12–7.27)	0.960	7.72(0.41–146.50)	0.174
pT stage				
Ta/T1(ref)	1			
T2	4.35(0.54–35.41)	0.169	25.73(1.10-599.90)	**0.043**
T3	2.77(0.33–23.04)	0.345	6.95(0.38–125.90)	0.190
T4	NA	0.998	NA	0.999
cN stage				
N0 (ref)	1		1	
N+	NA	NA	NA	NA
LVI				
No (ref)	1		1	
Yes	0.56(0.16-2.00)	0.371	0.65(0.12–3.47)	0.614
CIS				
No (ref)	1		1	
Yes	3.56(0.46–27.28)	0.222	46.37(0.02–100.90)	0.328
Laterality				
Left(ref)	1		1	
Right	0.63(0.21–1.88)	0.407	0.46(0.08–2.52)	0.370
Location				
Renal pelvis (ref)	1		1	
Ureter	0.67(0.22–1.99)	0.465	0.31(0.04–2.25)	0.247
Both	0.99(0.12–8.09)	0.994	NA	0.999
Tumor multifocality				
No (ref)	1		1	
Yes	0.82(0.11–6.30)	0.850	NA	0.998
Tumor size				
< 25 mm(ref)	1			
≥ 25 mm	1.08(0.38–3.09)	0.884	1.25(0.22–6.97)	0.801
Adjuvant chemotherapy				
Continued				

	Univariate		Multivariate	
	Hazard ratio (95% CI)	*p* value	Hazard ratio (95% CI)	*p* value
No (ref)	1		1	
Yes	0.82(0.28–2.36)	0.707	1.24(0.22–7.07)	0.810

Table 4. Univariate and multivariate Cox regression analysis of independent factors for intravesical recurrence-free survival in the subgroup of the 120 patients received post-operative intravesical chemotherapy. Significant values are in bold.

	Before IPTW		After IPTW	
Outcomes	HR (95%CI)	*P* value	HR (95%CI)	*P* value
Overall survival				
LNOBE (ref)	1		1	
SCRNU	1.22 (0.56–2.68)	0.615	1.61 (0.72–3.61)	0.249
Cancer-specific survival				
LNOBE (ref)	1		1	
SCRNU	1.26 (0.45–3.52)	0.664	1.82 (0.64–5.22)	0.264
Recurrence-free survival				
LNOBE (ref)	1		1	
SCRNU	0.59 (0.32–1.10)	0.096	0.73 (0.38–1.40)	0.345
Intravesical recurrence-free survival				
LNOBE (ref)	1		1	
SCRNU	0.17 (0.04–0.73)	**0.017**	0.17 (0.04–0.77)	**0.021**
Extravesical recurrence-free survival				
LNOBE (ref)	1		1	
SCRNU	1.26 (0.45–3.52)	0.664	1.34 (0.60–2.95)	0.475

Table 5. Cox regression analysis of surgery approach on the prognosis outcome after IPTW. Significant values are in bold. Adjusted for gender, age, BMI, hypertension, diabetes, ASA score, pre-operative GFR, pre-operative Cr, pT stage, cN stage, LVI, CIS, laterality, location, tumor size, post-operative intravesical chemotherapy, adjuvant chemotherapy.

1346 patients, also revealed that adjuvant chemotherapy was not a significant predictor of IVR[22]. Thus, the preventive benefits of adjuvant chemotherapy for IVR still need to be explored in large-scale studies.

Whether to perform retroperitoneal or preperitoneal surgery is highly debated. Some researchers have proposed a transperitoneal approach because of several advantages. Specifically, easy recognition of surgical anatomical landmarks and a wide surgical field of view make it easier for urologists to operate, and these features can effectively reduce operator fatigue due to compliance with ergonomics. This procedure is also more suitable for patients who are obese, have large tumours, have involvement of the perirenal fascia, and have a history of retroperitoneal surgery[23]. Some surgeons prefer the retroperitoneal approach to gain direct access to the renal artery and kidney, avoid bowel mobilization and use fewer trocars[24]. In a retrospective study, Liu et al. investigated 34 retroperitoneal LNU cases and 34 transperitoneal LNU cases and reported that the perioperative outcomes and oncological prognoses were similar[25]. Wang et al. reported that the retroperitoneal approach resulted in less blood loss, a shorter extubation time, and better oncological outcomes, including progression-free survival (PFS) and mortality at six months[26]. The gold standard surgical approach needs to be further investigated.

Although this single-centre study provides evidence for the feasibility and safety of SCRNU in the treatment of UTUC, several limitations should be noted. First, the retrospective design and lack of randomization may have introduced selection bias in patient enrolment and exclusion, thus limiting the generalizability of the findings. Second, the relatively small sample size and single-centre nature of the data may reduce the statistical power and robustness of the conclusions. Third, our study did not compare SCRNU with transperitoneal laparoscopic RNU, underscoring the need for future multicentre, large-scale, prospective randomized trials to verify the present results and assess different surgical approaches more comprehensively. Moreover, previous studies have reported favourable clinical outcomes with robot-assisted RNU[27], suggesting a potential direction for further optimization and refinement of surgical techniques.

Conclusion

Our study indicated that SCRNU not only avoids intraoperative repositioning but also improves perioperative outcomes, including reductions in operative time, blood loss, and length of hospital stay, and is associated with better IVRFS.

Data availability

The data that support the findings of this study are not openly available due to reasons of sensitivity and are available from the corresponding author upon reasonable request.

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Author contributions

LW, BF, and ZYL designed the study, provided critical revisions, and were responsible for overall project leadership and guaranteeing the integrity of the study. JQC, LXZ, and ZHD, as co-first authors, contributed equally to patient data analysis, result interpretation, and manuscript drafting. CC, HYT, and HPC were responsible for data collection, quality control, and assisting in analysis. ZWS contributed to the statistical review, ensuring accuracy, and reviewing the final manuscript. All authors reviewed and approved the final manuscript for submission, and agree to be accountable for all aspects of the work.

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Declarations

Competing interests
The authors declare no competing interests.

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