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Original Article

Robot-assisted nephroureterectomy: surgical and mid-term oncological outcomes in over 1100 patients (ROBUUST 2.0 collaborative group)

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Objective

To analyse surgical, functional, and mid-term oncological outcomes of robot-assisted nephroureterectomy (RANU) in a contemporary large multi-institutional setting.

Patients and Methods

Data were retrieved from the ROBotic surgery for Upper tract Urothelial cancer STtudy (ROBUUST) 2.0 database, an international, multicentre registry encompassing data of patients with upper urinary tract urothelial carcinoma undergoing curative surgery between 2015 and 2022. The analysis included all consecutive patients undergoing RANU except those with missing data in predictors. Detailed surgical, pathological, and postoperative functional data were recorded and analysed. Oncological time-to-event outcomes were: recurrence-free survival (RFS), metastasis-free survival (MFS), cancer-specific survival (CSS), and overall survival (OS). Survival analysis was performed using the Kaplan–Meier method, with a 3-year cut-off. A multivariable Cox proportional hazard model was built to evaluate predictors of each oncological outcome.

Results

A total of 1118 patients underwent RANU during the study period. The postoperative complications rate was 14.1%; the positive surgical margin rate was 4.7%. A postoperative median (interquartile range) estimated glomerular filtration rate decrease of −13.1 (−27.5 to 0) mL/min/1.73 m^2 from baseline was observed. The 3-year RFS was 59% and the 3-year MFS was 76%, with a 3-year OS and CSS of 76% and 88%, respectively. Significant predictors of worse oncological outcomes were bladder-cuff excision, high-grade tumour, pathological T stage ≥3, and nodal involvement.

Conclusions

The present study contributes to the growing body of evidence supporting the increasing adoption of RANU. The procedure consistently offers low surgical morbidity and can provide favourable mid-term oncological outcomes, mirroring those of open NU, even in non-organ-confined disease.

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Keywords

oncological outcomes, radical nephroureterectomy, robotic surgical procedure, surgical complications, upper urinary tract urothelial cancer

Introduction

Upper urinary tract urothelial carcinoma (UTUC) represents an uncommon type of UC, despite an uprising trend in its incidence over the last decade [1]. Radical nephroureterectomy (NU) with bladder-cuff excision (BCE) represents the mainstay of surgery with curative intent for patients with high-risk UTUC, and strict oncological principles must be abided to prevent tumour spillage [2]. Comparable oncological outcomes have been observed with both minimally invasive and open approaches [3,4].

Robot-assisted NU (RANU) seems to outperform traditional laparoscopy in terms of postoperative complications and shorter hospitalisation [5]. Given the limited reported data, uncertainties remain on the viability of RANU for locally advanced disease, as well as its oncological outcomes. Nevertheless, there is a rise in the implementation of robot-assisted procedures [6].

In the present study, we sought to analyse surgical, functional, and mid-term oncological outcomes of patients undergoing RANU in a large multi-institutional international setting.

Patients and Methods

Study Population and Variables

The ROBotic surgery for Upper tract Urothelial cancer STtudy (ROBUUST) 2.0 is an international, multicentre registry encompassing data of patients undergoing curative surgery—either NU or kidney-sparing surgery—for UTUC at participating centres between 2015 and 2022. Institutional Review Board (IRB) and data sharing approval were obtained at all centres (IRB 22111001). Patients underwent regular follow-up with quarterly urinary cytology and cystoscopy for the initial 2 years, and quarterly CT scans for the first year, followed by annual examinations thereafter. Data on patients with UTUC undergoing RANU were retrieved from the ROBUUST 2.0 database, including all consecutive patients except those with missing data in predictors.

Baseline variables were collected and described. Detailed operative data related to the surgical procedure were recorded and analysed as indicators of surgical outcomes. Intra- and postoperative complications were graded according to the standardised Clavien–Dindo classification [7]. Major complications were defined as Clavien–Dindo Grade ≥III. Pathological features included pathological T (pT) stage and grade, margin status, pN, and lymph node yield.

Early (serum creatinine level and estimated glomerular filtration rate [eGFR] at discharge) and mid-term (12 months and last follow-up) postoperative renal function, as well as eGFR variation between baseline and time of last follow-up, were considered as functional outcomes.

Oncological time-to-event outcomes were: recurrence-free survival (RFS), defined as the time elapsed between diagnosis and disease recurrence; metastasis-free survival (MFS), defined as the time elapsed between diagnosis and metastasis onset; cancer-specific survival (CSS); and overall survival (OS), defined as the time between diagnosis and tumour-related death or death by any cause, respectively.

Statistical Analysis

Statistical analysis was conducted according to published guidelines [8,9]. Medians and interquartile ranges (IQRs) were adopted to report continuous variables. Proportions and frequencies were used to report categorical variables. Predictors of postoperative complications were evaluated with multivariable logistic regression analysis. Local RFS, distant MFS, CSS and OS were estimated using the Kaplan–Meier method, with a 3-year cut-off. To assess oncological outcomes in patients with locally advanced disease, survival analysis data were stratified based on pT stage (≥pT3 vs ≤pT2), and the log-rank test was used to verify any statistical difference between subgroups. The follow-up duration was determined from the treatment to recurrence or metastasis at the last follow-up, for RFS and MFS respectively, and until death or last follow-up visit for CSS and OS. After adjusting for potential confounders, a multivariable Cox proportional hazard model was built to evaluate significant predictors of each oncological outcome. Stata®, version 17.0 (StataCorp LLC, College Station, TX, USA) was used for statistical analysis with statistical significance set at $P < 0.05$.

Results

Baseline Features

In the overall cohort, 1118 patients underwent RANU during the study period, with a median (IQR) follow-up of 36 (19–67)

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months. The majority were male (58.6%), and the median (IQR) age was 71 (64–78) years and the median (IQR) body mass index was 26.3 (24–29.4) kg/m^2. Almost one-third (28.6%) had a history of bladder cancer, with only 27 (2.4%) having undergone bladder removal before the diagnosis of UTUC. Additionally, the patients were predominantly classified as high risk according to European Association of Urology (92.5%), National Comprehensive Cancer Network (87%), and AUA (75.2%) guidelines. A total of 117 patients (10.5%) received neoadjuvant therapy before extirpative surgery (Table 1).

Table 1 Baseline features.

Variable	Value
Patients, *n*	1118
Age, years, median (IQR)	71 (64–78)
Sex, *n* (%)	
Male	655 (58.6)
Ethnicity, *n* (%)	
Caucasian	731 (63.1)
Black	151 (13.4)
Hispanic	87 (7.4)
Asian	134 (11.4)
Other	53 (4.6)
Smoker, *n* (%)	
Yes	253 (22.7)
Former	386 (34.6)
Boday mass index, kg/m^2, median (IQR)	26.3 (24–29.4)
ASA score, *n* (%)	
≥3	664 (59.4)
Solitary kidney, *n* (%)	9 (0.8)
History of BC, *n* (%)	
Low grade	157 (14)
High grade	164 (14.6)
Previous BC surgery, *n* (%)	
TURBT	284 (25.4)
Radical cystectomy	27 (2.4)
Symptoms, *n* (%)	
Haematuria	775 (69.3)
Flank pain	45 (4)
Asymptomatic	134 (12)
Other/unknown	164 (14.6)
Preoperative serum creatinine, μmol/L, median (IQR)	98.13 (79.56–123.76)
Preoperative eGFR, mL/min/1.73 m^2, median (IQR)	60 (48–79)
Tumour size, cam, median (IQR)	3 (2–4.6)
Multifocal, *n* (%)	245 (21.9)
Hydronephrosis, *n* (%)	530 (47.4)
Clinical tumour stage, *n* (%)	
cTa	233 (20.8)
cT1	479 (42.8)
cT2	165 (14.7)
cT3–4	167 (14.9)
Unknown	76 (6.8)
Clinical nodal stage, *n* (%)	
cN0	996 (89.1)
cN1	81 (7.2)
cN2	41 (3.7)
Unknown	
Metastatic disease, *n* (%)	35 (3.1)
Preoperative ureteroscopy, *n* (%)	667 (59.7)
Biopsy grade, *n* (%)	
Low grade	141/569 (24.8)
High grade	428/569 (75.2)
Risk stratification	
EAU High risk	1033 (92.4)
NCCN High risk	971 (86.8)
AUA High risk	569 (75.2)
Neoadjuvant therapy, *n* (%)	117 (10.5)

ASA, American Society of Anesthesiologists; BC, bladder cancer; EAU, European Association of Urology; NCCN, National Comprehensive Cancer Network; TURBT, transurethral resection of bladder tumour.

Surgical and Pathological Outcomes

A complete description of perioperative outcomes is presented in Table 2. Surgical procedures were performed with the da Vinci® Xi (Intuitive Surgical Inc., Sunnyvale, CA, USA) in 69.1% of the cases, predominantly in a transperitoneal fashion (97.8%). More than two-thirds (69.2%) of the procedures were 'single stage', meaning that the patient remained in the same position throughout the procedure, and the most common bladder-cuff management was a robot-assisted extravesical approach (72.2%), with only 8.6% of the procedures being completed without BCE. A lymph node dissection (LND) was carried out in 42.3% of the cases. The median (IQR) operative time was 212.5 (161–280) min and the estimated blood loss (EBL) was 100 (50–150) mL. Intraoperative complications occurred in 2.7% of cases, including 10 (0.7%) cases marked by extensive peritumoral adhesions and three cases of intraoperative bowel injuries. Among the 122 patients who underwent neoadjuvant chemotherapy, one patient exhibited a dense desmoplastic reaction at the surgical site, and another procedure was aborted due to severe adhesions, hindering adequate control of vascular elements. Postoperative complications affected 14.1% of patients, with 3.7% classified as major. A detailed description of type and Clavien–Dindo grade of complications is provided in Table S1. The median (IQR) length of stay (LOS) was 3 (2–5) days, with a 6.3% re-admission rate. At multivariable analysis, significant predictors of complications were age (odds ratio [OR] 1.34, 95% CI 1.02–1.74) and EBL (OR 1.19, 95% CI 1.05–1.35; Table 3). Histopathological examination revealed a locally advanced disease (stage ≥pT3) in 36.6% of the patients, most commonly of high grade (79.2%). The positive surgical margin (PSM) rate was 4.7%.

Postoperative early (median [IQR] eGFR 46 [36–58] mL/min/1.73 m^2) and mid-term (median [IQR] eGFR 48 [38–61] mL/min/1.73 m^2), and last follow-up (median [IQR] eGFR 48 [35.5–61.5] mL/min/1.73 m^2) renal function resulted in a median (IQR) eGFR variation of −13.1 (−27.8 to 0) mL/min/1.73 m^2 from baseline.

Survival Analysis

After excluding patients with missing data at follow-up, 1018 patients were included in the survival analysis. Disease

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Table 2 Surgical and pathological features of the 1118 patients.

Variable	Value
Robotic system, n (%)	
S/Si	148 (13.2)
Xi	773 (69.1)
SP	3 (0.3)
Other/unknown	194 (17.3)
Approach, *n* (%)	
Transperitoneal	1093 (97.8)
Single-stage procedure, *n* (%)	774 (69.2)
Operativ time, min, median (IQR)	212.5 (161–280)
EBL, mL, median (IQR)	100 (50–150)
Bladder-cuff management, *n* (%)	
Open intravesical excision	82 (7.3)
Open extravesical excision	6 (0.5)
Robot-assisted transvesical	97 (8.7)
Robot-assisted extravesical	807 (72.2)
Pluck technique	9 (0.8)
Stripping/intussusception	21 (1.9)
Not removed	96 (8.6)
LND, *n* (%)	473 (42.3)
Intraoperative complications	30 (2.7)
30-day postoperative complications, *n/N* (%)	
Yes	158 (14.1)
Clavien–Dindo Grade ≥III	41 (3.7)
Re-admission	59/846 (6.3)
LOS, days, median (IQR)	3 (2–5)
Pathological T stage, *n* (%)	
pTa	292 (26.1)
pTis	46 (4.1)
pT1	225 (20.1)
pT2	134 (12)
pT3–4	409 (36.6)
Other/unknown	12 (1.1)
Tumour grade, *n* (%)	
High grade	886 (79.2)
PSM, *n* (%)	53 (4.7)
pN, *n* (%)	
pN0	398 (35.6)
≥pN1	111 (9.9)
pNx	609 (54.5)
Lymph node yield, *n*, median (IQR)	1 (0–6)
Adjuvant treatments, *n/N* (%)	
Bladder instillation	335/1094 (30.6)
Systemic therapy	153/1001 (15.3)
Postoperative serum creatinine, μmol/L, median (IQR)	
Discharge	126.41 (103.43–155.59)
12 months	132.60 (108.73–167.96)
Last follow-up	128.18 (106.08–167.96)
Postoperative eGFR, mL/min/1.73 m^2, median (IQR)	
Discharge	46 (36–58)
12 months	49 (38–62)
Last follow-up	48 (35.5–61.5)
ΔeGFR	−13 (−27.5 to 0)

EBL, Estimated Blood Loss; eGFR, estimated Glomerular Filtration Rate; LND, Lymph Node Dissection; LOS, Length of Stay, PSM, Positive Surgical Margins.

Table 3 Multivariable logistic regression analysis of predictors of complications.

Postoperative complications	Adjusted OR (95% CI)	*P*
Age	1.34 (1.02–1.74)	**0.03**
ASA	1.53 (0.84–2.77)	0.156
Body mass index	1.08 (0.49–1.71)	0.782
Solitary kidney		
No	Ref	0.558
Yes	2.57 (0.83–3.32)	
Neoadjuvant therapy		
No	Ref	0.744
Yes	1.23 (0.35–4.28)	
Robotic platform*		
S/Si	Ref	0.742
Xi	0.85 (0.34–2.13)	
Single-stage surgery		
No	Ref	0.193
Yes	0.60 (0.28–1.28)	
Operative time	0.99 (0.64–1.33)	0.961
EBL	1.19 (1.03–1.35)	**0.01**
BCE		
No	Ref	0.318
Yes	1.82 (0.56–5.93)	
LND		
No	Ref	0.115
Yes	1.66 (0.88–3.14)	
Pathological stage		
pTa	Ref	
pTis	1.57 (0.38–6.46)	0.532
pT1	0.39 (0.11–1.32)	0.131
pT2	1.15 (0.39–3.38)	0.799
pT3	1.28 (0.53–3.06)	0.573
pT4	0.82 (0.15–4.42)	0.818
Pathological grade		
Low grade	Ref	0.258
High grade	0.60 (0.24–1.45)	

*ASA, American Society of Anesthesiology; BCE, Bladder Cuff Excision; EBL, Estimated Blood Loss; LND, Lymph Node Dissection. *SP surgery excluded due to low number of observations. Bold values statistically significant at P < 0.05.*

recurrence was observed in 349 (34.3%) patients, with a 3-year RFS of 59%. Significant predictors of RFS were high-grade tumours at final pathology (hazard ratio [HR] 2.20, 95% CI 1.43–3.38) and not performing BCE (HR 2.01, 95% CI 1.02–3.96). The onset of metastatic disease was registered in 183 (18%) patients, achieving a 3-year MFS of 76%, with pT3 (HR 5.15, 95% CI 2.16–12.28), pT4 (HR 5.59, 95% CI 4.16–5.84), pN2 (HR 4.48, 95% CI 2.66–7.54), high-grade (HR 4.62, 95% CI 1.39–5.26) tumours being statistically significantly related to a higher likelihood of metastatic disease. Over the study period, 185 (18.2%) patients died with a 3-year OS of 76%. Patients facing major postoperative complications (HR 2.28, 95% CI 1.12–4.65), with pT4 tumours (HR 5.37, 95% CI 2.23–12.91), and pN2 disease (HR 4.55, 95% CI 2.44–8.47) were at higher risk of death from any cause. When assessing CSS, 88 (8.6%) patients had a cancer-related death, with a 3-year CSS of 88%. Stage ≥pT3 (pT3: HR 3.80, 95% CI 1.23–11.74; pT4: HR 3.48, 95% CI 2.62–4.57) and nodal involvement ≥pN1 (pN1: HR 3.51, 95% CI 1.24–9.96; pN2: HR 4.59, 95% CI 2.06–9.72; pN3: HR 5.96, 95% CI 4.69–7.89) posed an increased risk of cancer-related death. A detailed description of the sites of recurrence and metastasis is provided in Table S2, while the multivariable Cox regression analysis concerning oncological outcomes is provided in Table S3.

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At the 3-year follow-up, patients with locally advanced disease (≥pT3) had significantly worse outcomes (RFS: 61% vs 53%; MFS: 88% vs 54%, OS: 84% vs 60%; CSS: 94% vs 76%, all $P < 0.01$) compared to those with organ-confined disease (≤pT2; Fig. 1A–D).

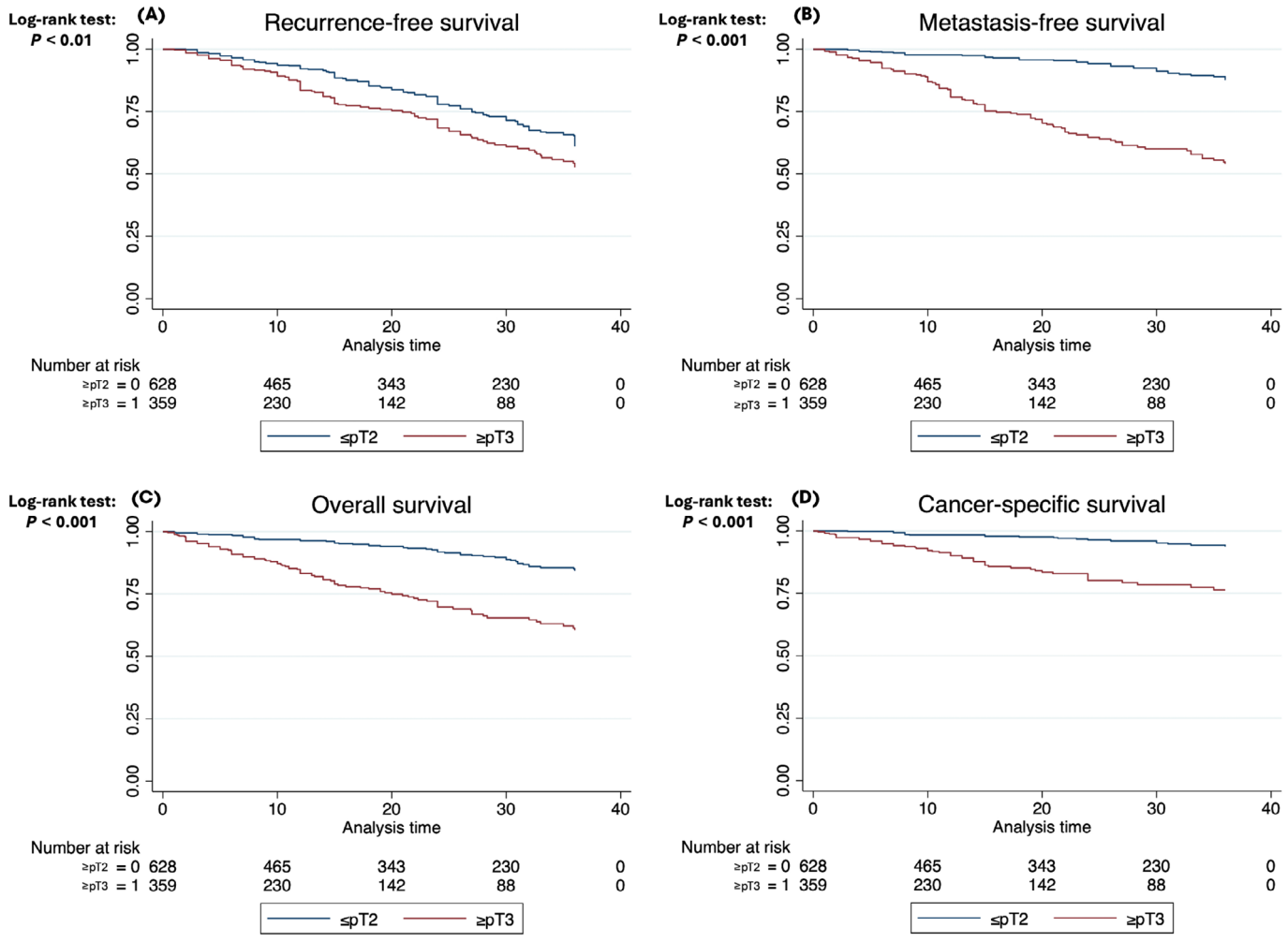
Discussion

To the best of our knowledge, we report the largest multi-institutional contemporary series of RANU to date. Overall, our findings suggest that RANU offers low surgical morbidity and favourable oncological outcomes.

Real-world data gathered from population-based studies has shown a progressive increase in the use of RANU [10,11], correlating with the expanding adoption of robotic platforms throughout different hospital settings, and the growing experience in their application within the urological field [12]. In our cohort, the rate of intraoperative complications remained extremely low at 2.7%. The robot-assisted approach outperformed both open surgery and traditional laparoscopy in terms of intraoperative complications [5,13]. When comparing the two minimally invasive approaches, laparoscopic NU exhibited a 4% incidence of intraoperative complications, while RANU demonstrated only half of that, at 2% [14]. Indeed, the introduction of robotic surgery allowed us to overcome some of the limitations of the laparoscopic approach, especially when performing BCE.

Moreover, in our cohort, the incidence of any grade and major 30-day postoperative complications was 14.1% and 3.7%, respectively. The median LOS was 3 days, with a re-admission rate of 6.3%. In the subset of procedures performed after systemic chemotherapy, two were surgically demanding due to the presence of severe adhesions, and, of these, one was aborted. However, the administration of neoadjuvant chemotherapy was not a significant predictor of 30-day postoperative complications. Thus, our data corroborate the feasibility and safety of RANU in this setting. Conversely, age and EBL were significant predictors of

Fig. 1 Survival analysis comparing ≤pT2 and ≥pT3 groups for time-to-event oncological outcomes. (**A**) RFS. (**B**) MFS. (**C**) OS. (**D**) CSS.



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postoperative complications at multivariable logistic regression analysis. Significant variation exists in the incidence of postoperative complications among available case series, spanning from 6.6% to 25% for any-grade complications and from 2.6% to 7.1% for major complications [15–18]. In line with our results, Trudeau et al. [19] reported an overall postoperative complications rate of 11.9% in a large population-based analysis of 1914 RANUs. This fluctuation, alongside disparities between these rates and our incidence rates, likely arises from differences in cohort sample sizes, which were considerably smaller (<100 patients), as well as heterogeneity in baseline characteristics and pathological features among the patients involved. Similarly, a certain variability across involved institutions may be inferred. This could be potentially driven by differences in the thoroughness with which each institution collects and classifies complications, especially major complications. This heterogeneity also concerns predictors of postoperative complications. While some authors have identified age and EBL as significant risk factors, others contradicted these results [20–22]. Despite the increasing adoption of grading classifications in the field of urology [23], the observed variability may derive from the lack of standardisation in the classification and reporting of postoperative complications [24], making literature interpretation difficult and the recognition of adverse events inconsistent across different studies. Moreover, when modelling surgical features as possible predictors of postoperative complications, various measured and unmeasured factors may bias results. In our multivariable analysis, we were able to assess several pre- and intraoperative possible confounders, leveraging a large sample size and enough events, therefore enhancing the reliability of our findings.

The greatest uncertainty concerns the oncological outcomes of patients with locally advanced UTUC, for which the open approach is still recommended [2]. Within our cohort, despite the proportion of pT3–4 tumours exceeding 30%, the incidence of PSMs remained <5%. In a multi-institutional analysis of 472 patients undergoing open NU, showcasing a 35.2% rate of pT3–4 stage tumours, the PSM rate was double the one we observed with RANU (9.3%) [25]. Indeed, in a population-based analysis by Rodriguez et al. [3], RANU was significantly related to a decreased PSM risk, compared to the open approach, possibly attributed to improved tissue dissection, particularly in cases of local advancement. This holds particular significance when considering the prognostic impact of PSMs on the oncological outcomes of these patients [25].

In our cohort, we observed a 3-year RFS of 59%, and a 3-year MFS of 76%, while 3-year OS and CSS were 76% and 88%, respectively. These results are comparable to those reported in the smaller case series found in the current literature [15,17,18] and, more significantly, with studies comparing RANU with open NU [26]. The recommendation favouring open over minimally invasive NU for non-organ-confined UTUC stems from a randomised trial comparison between open and laparoscopic approach, wherein an advantage in terms of CSS and MFS for pT3 patients was observed following open NU [27]. However, its validity is limited by the small sample size (80 patients), absence of preoperative patient details, and unreported rate of possible conversions from laparoscopic to open surgery. To fill this gap in the current literature, we conducted a sub-analysis on patients with ≥pT3 stage in the largest multi-institutional cohort available to date. In our study, patients with ≥pT3 experienced a 3-year RFS of 53%, and a 3-year MFS of 54%. Moreover, a 3-year OS of 70%, with a CSS of 76% was observed. At the same cut-off point, in a multi-institutional case series encompassing data from 1363 patients undergoing open NU, Margulis et al. [28] observed similar outcomes for patients with ≥pT3 stage. Stratification of survival endpoints by pT stage is often under-reported and long-term follow-up data are sparse. However, oncological outcomes appear to be primarily driven by disease-specific factors rather than the surgical approach. Indeed, in a large single-centre case series including 422 patients receiving NU via either an open, laparoscopic, or robot-assisted approach, survival outcomes were significantly worse for those above ≥pT3 up to 10 years after surgery, irrespective of the surgical approach [29].

Moreover, consistency was noted between ours and previous reports regarding factors impacting survival and disease recurrence [15,18,28,29]. Indeed, the execution of BCE emerged as a significant predictor of RFS at Cox multivariate analysis. BCE and subsequent bladder closure is a pivotal step of NU, given the risk of disease relapse in the ureteric stump and bladder [30]. The most common approach to bladder cuff in the present study involved robot-assisted extravesical excision. A large meta-analysis comparing oncological outcomes of laparoscopic and open NU, raised the issue of a potential adverse impact of laparoscopic BCE on oncological outcomes [31]. However, BCE was performed using an open approach in most of the meta-analysed studies, questioning the association between this surgical step and the approach. On the other hand, the advocated advantage of RANU lies in the avoidance of patient repositioning and cart movement, thereby enhancing exposure during distal ureterectomy and bladder-cuff closure [32].

Pathological features exerted a significant impact on MFS and CSS, as indicated by our survival analysis. This effect may be due to the high rate of upstaging of locally advanced disease observed between preoperative tumour staging and final histological assessment. Indeed, in our cohort, patients with locally advanced disease (≥pT3) had an increased risk of cancer-specific mortality. Accordingly, an opposite relationship between pT stage and CSS has been previously reported by Rosiello et al. [33] in a population-based analysis,

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with patients' prognosis significantly deteriorating for stages ≥pT2. Furthermore, patients with lymph node involvement faced a higher risk of unfavourable outcomes in terms of MFS and CSS. The lymph node yield and the degree of nodal involvement were negatively related to both CSS and OS in a comparative analysis among laparoscopic, open NU, and RANU, regardless of the surgical approach [26]. However, an increased odds of LND, leading to higher lymph node yield has been observed with RANU [34]. Considering these results, this represents an additional benefit of this approach.

Overall, the results of this multi-institutional analysis confirm the viability of RANU in all the scenarios of UTUC management. If oncological radicality is maintained to achieve negative surgical margins, RANU should be regarded as equally effective as open NU. The validity of our findings is further strengthened by the large sample size and the multi-institutional setting that broadens its generalisability to both academic and real-world scenarios.

However, our study is not without limitations. The retrospective design may introduce selection bias, and variations in follow-up protocols and surgical techniques could exist due to the multi-institutional nature of the dataset. Variability in bladder-cuff management and the absence of standardised LND templates were observed across the involved institutions. Additionally, it should be noted that only a small portion of the cohort received adjuvant therapy, which is currently the standard of care for patients with muscle-invasive disease and nodal involvement. Although these factors were included in the multivariable Cox regression analysis, they might still have influenced the oncological outcomes. Nevertheless, follow-up visits were conducted according to current guidelines, and surgeries were conducted by experienced urological surgeons at tertiary referral centres following standardised techniques [35], partially mitigating this source of disparity. The lack of centralised reviews for pathological assessments adds an extra limitation, notwithstanding the presence of dedicated uropathologists at each institution involved in this consortium. Finally, the lack of a standardised definition for postoperative complications may lead to discrepancies in their registration and classification.

In conclusion, the present study contributes to the growing body of evidence supporting the increasing adoption of RANU in diverse clinical settings. RANU is associated with low perioperative complications and a low PSM rate. Its favourable oncological outcomes are comparable to those achieved through open NU, including in case of non-organ-confined disease.

Disclosure of Interests

The authors have no conflict of interest to declare.

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None.

Ethics Statement

All patients provided informed consent before inclusion in the study. The study was conducted in accordance with the principles of the Helsinki Declaration.

Author Contributions

Conception and design: Autorino, Ditonno; Acquisition of data: Ditonno, Franco, Wang, Abdollah, Amparore, Bhanvadia, Broenimann, Puri, Mendiola, Ben-David, Moon, Yong, Moghaddam, Ghoreifi, Bologna, Licari, Finati, Tuderti, Helstrom, Tozzi, Tufano; Analysis and interpretation of data: Ditonno, Wu, Ferro, Correa, Perdonà, Simone, Rais-Bahrami, Sundaram, Mehrazin, Gonzalgo, Derweesh, Porpiglia, Singla, Margulis, Antonelli, Djaladat, Autorino; Drafting of the manuscript: Ditonno; Critical revision of the manuscript for important intellectual content: Franco, Wang, Abdollah, Simone, Amparore, Bhanvadia, Broenimann, Puri, Mendiola, Ben-David, Moon, Yong, Moghaddam, Ghoreifi, Bologna, Licari, Finati, Tuderti, Helstrom, Tozzi, Tufano, Wu, Ferro, Correa, Perdonà, Rais-Bahrami, Sundaram, Mehrazin, Gonzalgo, Derweesh, Porpiglia, Singla, Margulis, Antonelli, Djaladat; Autorino; Supervision: Autorino; Final approval of the version to be published: Ditonno, Franco, Wang, Abdollah, Simone, Amparore, Bhanvadia, Broenimann, Puri, Mendiola, Ben-David, Moon, Yong, Moghaddam, Ghoreifi, Bologna, Licari, Finati, Tuderti, Helstrom, Tozzi, Tufano, Wu, Ferro, Correa, Perdonà, Rais-Bahrami, Sundaram, Mehrazin, Gonzalgo, Derweesh, Porpiglia, Singla, Margulis, Antonelli, Djaladat, Autorino; Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Ditonno, Franco, Wang, Abdollah, Simone, Amparore, Bhanvadia, Broenimann, Puri, Mendiola, Ben-David, Moon, Yong, Moghaddam, Ghoreifi, Bologna, Licari, Finati, Tuderti, Helstrom, Tozzi, Tufano, Wu, Ferro, Correa, Perdonà, Rais-Bahrami, Sundaram, Mehrazin, Gonzalgo, Derweesh, Porpiglia, Singla, Margulis, Antonelli, Djaladat, Autorino; All authors read and approved the final version of the manuscript.

Data Availability Statement

The data sets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Abbreviations: BCE, bladder-cuff excision; CSS, cancer-specific survival; EBL, estimated blood loss; eGFR, estimated glomerular filtration rate; HR, hazard ratio; IQR, interquartile range; IRB, Institutional Review Board; LND, lymph node dissection; LOS, length of stay; MFS, metastasis-free survival; (RA)NU, (robot-assisted) nephroureterectomy; OR, odds ratio; OS, overall survival; PSM, positive surgical margin; pT, pathological T (stage); RFS, recurrence-free survival; ROBUUST, ROBotic surgery for Upper tract Urothelial cancer STtudy; (UT)UC, upper urinary tract urothelial carcinoma.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. Description of type and grade of perioperative complications.

Table S2. Site of recurrences and metastasis.

Table S3. Multivariable Cox regression analysis of oncological outcomes.

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