Brief Communication | **Open Access**

Mini-invasive Surgery

Alli *et al. Mini-invasive Surg.* 2026;10:25 **DOI:**10.20517/2574-1225.2025.178

Feasibility, safety, and outcomes of single-port robot assisted nephroureterectomy: early single center experience

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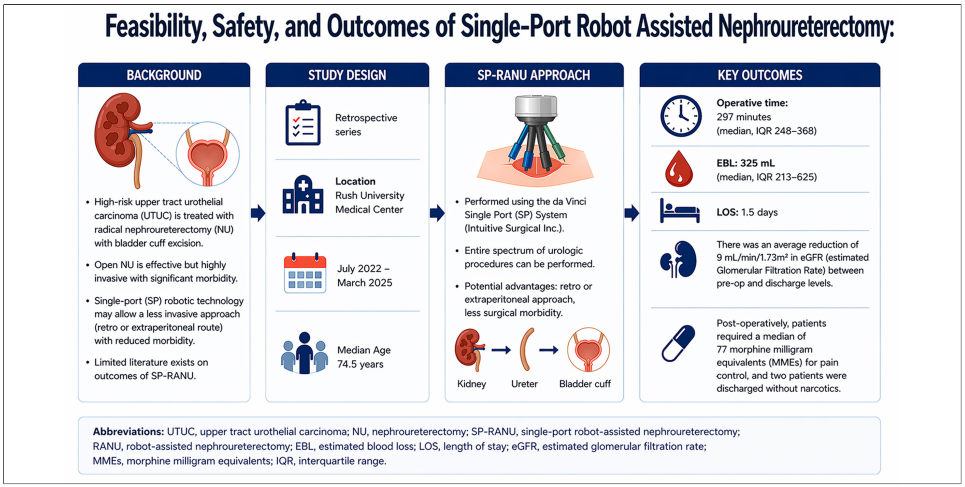
Keywords:
Single port, nephroureterectomy, robotic surgery, urothelial cell carcinoma

Citation: Alli NK, Casey KW, Langbo WA, Alli AHO, Biasatti A, Autorino R, Vourganti S, Reisz PA. Feasibility, safety, and outcomes of single-port robot assisted nephroureterectomy: early single center experience. *Mini-invasive Surg.* 2026;10:25. https://dx.doi.org/10.20517/2574-1225.2025.178

Received: 29 Dec 2025 **First Decision:** 15 Apr 2026 **Revised:** 23 May 2026 **Accepted:** 25 Jun 2026 **Published:** 3 Jul 2026

Academic Editors: Richard Naspro, Giulio Belli **Copy Editor:** Pei-Yun Wang **Production Editor:** Pei-Yun Wang



Abstract

Aim: Upper tract urothelial carcinoma (UTUC) is an aggressive malignancy historically managed with radical nephroureterectomy (NU). While multiport robot-assisted NU (MP-RANU) offers advantages over open surgery, data on single-port RANU (SP-RANU) remains limited. We aim to describe a single-institution's experience with SP-RANU and evaluate its feasibility, safety, and early outcomes.

Methods: A retrospective review of SP-RANU procedures completed at a tertiary academic center was conducted. Demographic information, clinical data, tumor characteristics, operative details, and postoperative outcomes were recorded.

Results: Between July 2022 and March 2025, six patients underwent SP-RANU [median age 75 years, interquartile range (IQR) 68-77]. Median operative time was 297 min (IQR 248-368), median estimated blood loss was 325 mL (IQR 213-625), and no intraoperative complications were reported. Median hospital length of stay (LOS) was 1.5 days (IQR 1-5).

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Two patients experienced Clavien-Dindo grade II complications. Five patients achieved negative oncologic margins, one patient underwent SP-RANU for non-oncologic indications, and one patient developed distant nodal metastasis noted after surgery. There was a median reduction of 9 mL/min/1.73 m^2 in estimated glomerular filtration rate (eGFR) between pre-op and discharge levels. Post-operatively, patients required a median of 77 morphine milligram equivalents (MMEs) for pain control, and two patients were discharged without narcotics.

Conclusion: SP-RANU offers regionalization of surgery, low intraoperative morbidity, decreased opioid requirements, short LOS, and promising early perioperative outcomes in carefully selected patients. This data supports SP-RANU as a viable minimally invasive surgical option, with need for further evaluation in a larger comparative cohort.

INTRODUCTION

Upper tract urothelial carcinoma (UTUC) is a clinically aggressive malignancy arising from the urothelium of the renal pelvis and ureter[1]. High-risk disease is frequently diagnosed at an advanced stage and most often leads to surgical intervention. Although open radical nephroureterectomy (NU) with bladder-cuff excision was historically the gold standard, this is a highly invasive operation associated with significant perioperative morbidity[1]. Over the last three decades, surgeons have increasingly adopted minimally invasive techniques to reduce operative morbidity while maintaining oncologic control[2]. As current uro-oncology advances toward risk-stratified and biomarker-informed care, surgical approaches must also balance oncologic effectiveness with patient-specific morbidity and recovery outcomes.

Reflecting this evolution, robot-assisted nephroureterectomy (RANU) on multiport (MP) platforms provides enhanced visualization and wristed instrumentation through several small incisions and has demonstrated favorable perioperative profiles relative to open surgery[3]. More recently, the da Vinci single-port (SP) platform has enabled true single-site access and facilitated retroperitoneal and extraperitoneal approaches, expanding the surgical options for complex cases[4]. In the context of NU, these features translate into avoiding the peritoneum altogether with a small single incision allowing retroperitoneal access, reduced bowel manipulation, decreased postoperative pain, and shorter convalescence, preserving the ability to perform multi-quadrant operations through a single docking site[5,6]. Regarding oncologic control and renal function, a 105-patient study comparing single-port RANU (SP-RANU) and multiport RANU (MP-RANU) demonstrated no statistically significant differences in surgical outcomes, one-year renal function decline, or tumor (T) stage[7].

Despite the uptake of SP techniques across urology, evidence specific to SP-RANU remains limited. Published reports consist largely of feasibility series and institutional experiences describing techniques, access routes, and early outcomes[8,9]. Robust data that benchmark SP-RANU are needed to clarify safety, reproducibility, and oncologic equivalence. Additionally, more data is needed to guide standardization of operative workflow and define where SP-RANU may best fit within individualized treatment algorithms for UTUC[1,2].

Herein we describe our initial series of SP-RANU, detailing and characterizing short-term intraoperative, perioperative, and postoperative outcomes.

METHODS

Study design

Approved by Rush IRB with consent waived, a retrospective review was conducted for all patients undergoing SP-RANU by three fellowship-trained urologic surgeons at Rush University Medical Center between July 2022 and March 2025. Inclusion criteria were age greater than or equal to 18 years, and

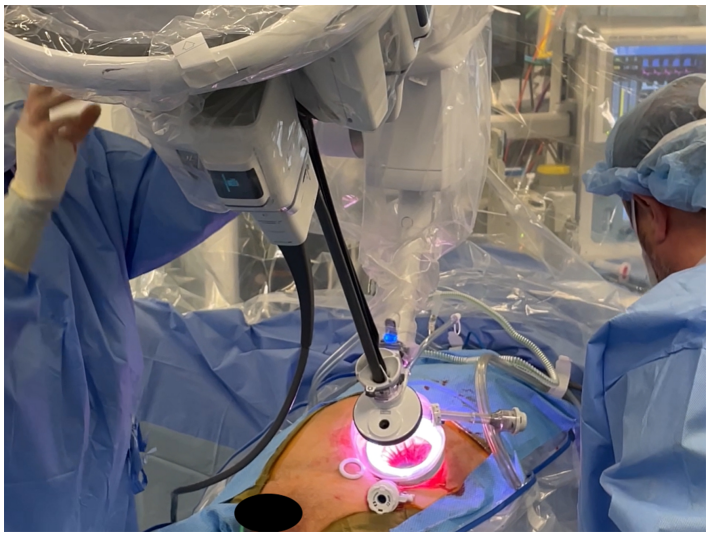

Figure 1. Port placement showing SP robot docked and a sidecar assistant port. SP: Single-port.

SP-RANU performed at our institution. Exclusion criteria were age less than 18 years, NU performed using a MP robotic, laparoscopic, or open approach, and incomplete perioperative records precluding extraction of key outcomes. Selection of the SP approach was based on surgeon discretion, considering patient anatomy, prior surgical history, disease characteristics, and perceived technical feasibility. Median follow-up was 1 month (range, 1-7 months). Pre-operative data was collected including patient demographics, baseline renal function, prior abdominal surgical history, tumor size and location, and prior oncologic workup. Data was compiled from operative reports including surgical approach, hilar management technique, intravesical chemotherapy, operative time, and blood loss. Post-operative variables were assessed, including complications, tumor staging, tumor recurrence, and postoperative renal function.

Surgical technique

Informed consent was obtained, and patients were brought to the operating room. General anesthesia was induced and a 16 French Foley catheter was placed. Patients were then positioned according to the planned surgical approach described below.

Retroperitoneal lower anterior approach

Patients undergoing a lower anterior approach (LAA) were placed in a modified supine position with their arms extended and secured to the bed. Supine LAA was obtained through a 6 cm incision made two finger breadths medial to the anterior superior iliac spine. Blunt dissection was performed to the level of the fascia, which was then scored with electrocautery and divided. The retroperitoneal space was developed bluntly with finger dissection. A small (4-7 cm) access port was then inserted through the fascial incision, and the da Vinci SP Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) was docked [Figure 1]. This configuration was selected to optimize retroperitoneal access and multi-quadrant reach while minimizing additional incisions. However, this series was not designed to evaluate its independent effects on operative time or complications.

The retroperitoneal space was developed with a combination of sharp and blunt dissection until the psoas muscle was encountered. The dissection was then carried cephalad, maintaining the external position of the SP robot aimed at the contralateral shoulder. The ureter was identified, clipped at the mid-ureter, and then dissected proximally toward the renal hilum. The renal artery and vein were then ligated with staples or clips and subsequently divided [Figure 2]. The ureter was then traced distally over the iliac vessels. At this point,

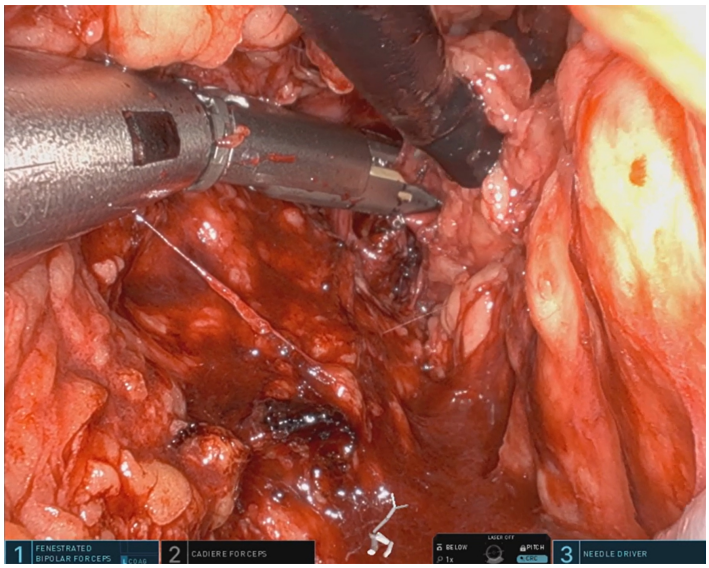

Figure 2. SP stapler used to control the hilum. SP: Single-port.

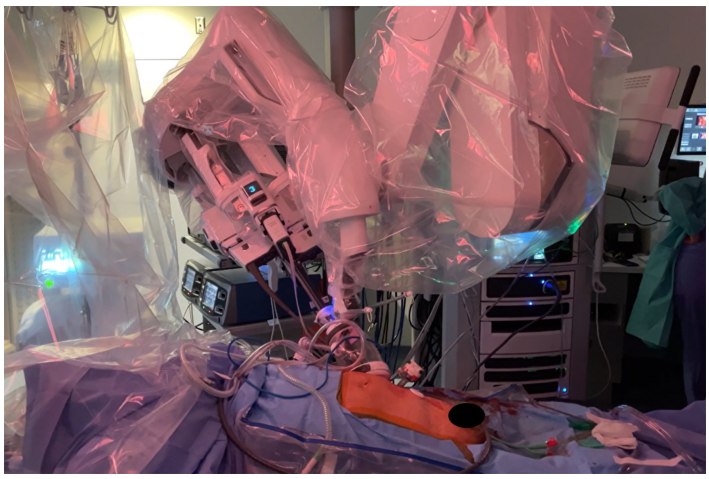

Figure 3. SP robot directed towards the pelvis for bladder cuff resection. SP: Single-port.

the SP robot was redirected towards the bladder [Figure 3]. The bladder was distended via the existing Foley catheter, and the ureter was freed distally to the intraluminal ureter. A wide bladder cuff was excised, and the resultant cystotomy was closed with running 3-0 V-lock suture [Figure 4]. The SP robot was then redirected toward the kidney. The remainder of the renal attachments were then divided, and the specimen was freed, secured within an endoscopic bag, and removed through the existing single port incision.

Transperitoneal lateral flank approach

Patients undergoing lateral flank approach (LFA) were placed in a lateral decubitus position and secured to the bed. The bed was then flexed to maximally expose the flank. A Veress needle was inserted at Palmer's Point, and the peritoneum was insufflated. A 3 cm incision was then made at the tip of the 12th rib, just lateral to the rectus abdominis, and carried down to the underlying fascia, which was incised. The muscle fibers were bluntly split, and the posterior fascia was sharply incised. The tract was dilated with a single port trocar; an occlusion device was advanced into the peritoneum, and the single port robot was docked.

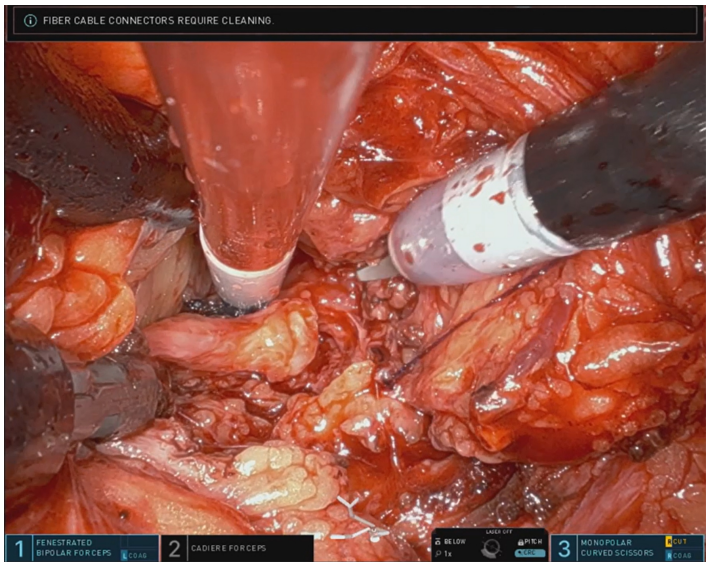

Figure 4. Bladder cuff resection performed with SP robot. SP: Single-port.

The colon was reflected medially allowing entry to the retroperitoneal space. The renal hilum was identified, and the renal artery and vein were ligated. The remainder of the kidney was dissected and freed from superior, posterior, and lateral attachments. The ureter was then dissected distally towards the pelvis and clipped and divided just proximal to the bladder wall. The freed specimen was then secured within an endoscopic bag and removed through the existing single port incision.

Data analysis

Pre-operative, intra-operative, and post-operative data were assessed as categorical data or continuous data. Statistical analysis was performed using Microsoft Excel (Version 16.61.1, Microsoft Corp, Redmond, WA). Continuous variables were summarized using medians with interquartile ranges (IQR), while categorical variables were reported as frequencies and percentages. Data points were entered into a structured Excel database, where calculations of summary statistics and generation of descriptive tables were performed. Given the limited sample size, descriptive analysis was performed without comparative, matched cohort, or survival analyses.

RESULTS

Six SP-RANU cases were included in this analysis [Table 1]. Four patients were male (67%), and two (33%) patients were female. The median age at surgery was 75 years (IQR 68-77). All patients had a prior history of abdominal surgery. All patients had American Society of Anesthesiologists (ASA) scores ranging from 2 to 3 and Eastern Cooperative Oncology Group (ECOG) performance status ranging from 0 to 2.

Four patients (67%) underwent SP-RANU via low anterior access, while two patients (33%) underwent surgery via lateral flank access. Median operative time was 297 min (IQR 248-368) and median estimated blood loss was 325 mL (IQR 213-625). There were no documented intraoperative complications.

Five cases of SP-RANU were performed for oncologic indications. The five tumors removed had tumor grades ranging from pTa to pT3. One case of SP-RANU was performed in the setting of an atrophic kidney with severe hydronephrosis and known ureteral stricture. Lymph node dissection was performed in one procedure with one ipsilateral perihilar lymph node removed. The pathology of both the tumor and lymph node from this specimen revealed high-grade urothelial carcinoma. This was the highest graded tumor of the

Table 1. Pre-operative, peri-operative, and post-operative factors of patients undergoing SP-RANU

Factor	Value
Pre-operative	
Sex	
Male, *n* (%)	4 (67)
Female, *n* (%)	2 (33)
Age, median years (IQR)	75 (68-77)
BMI, median kg/m^2 (IQR)	28 (23-32)
Race	
Hispanic/Latino, *n* (%)	2 (33)
Caucasian, *n* (%)	4 (67)
Smoking history, *n* (%)	3 (50)
Prior surgical history	
Appendectomy, *n* (%)	3 (50)
Hysterectomy, *n* (%)	2 (33)
Cholecystectomy, *n* (%)	2 (33)
Comorbidities	
Hypertension, *n* (%)	3 (50)
Diabetes mellitus, *n* (%)	4 (67)
CKD Stage, median (IQR)	2 (2-2.75)
ASA Score, median (IQR)	3 (3-3)
ECOG Performance Status, median (IQR)	1 (0.25-1.75)
Creatinine, median mg/dL (IQR)	1.1 (0.9-1.2)
eGFR, median mL/min/1.73 m^2 (IQR)	72 (67-78)
Peri-operative	
Access	
Lower anterior access (LAA), *n* (%)	4 (67)
Lateral flank access (LFA), *n* (%)	2 (33)
Operative time, median minutes (IQR)	297 (248-368)
Estimated blood loss, median mL (IQR)	325 (213-625)
Tumor size in largest dimension, median cm (IQR)	2.5 (2.5-4.0)
Tumor grade	
NA (non-oncologic operation), *n* (%)	1 (17)
pTa, *n* (%)	2 (33)
pT1, *n* (%)	1 (17)
pT3N0, *n* (%)	1 (17)
pT3N1, *n* (%)	1 (17)
Post-operative	
Postoperative inpatient MMEs, median mg (IQR)	77 (29.1-114.8)
Postoperative discharge MMEs, median mg (IQR)	45 (0-101.3)
POD#1 creatinine, median mg/dL (IQR)	1.3 (1.2-1.6)
POD#1 eGFR, median mL/min/1.73 m^2 (IQR)	58 (45-67)
Day of discharge creatinine, median mg/dL (IQR)	1.2 (1.1-1.7)
Day of discharge eGFR, median mL/min/1.73 m^2 (IQR)	66 (42-71)
Positive margins, *n* (%)	0 (0)
Evidence of local recurrence, *n* (%)	0 (0)
30-day readmission rate, *n* (%)	2 (33%)

Creatinine reported in mg/dL; eGFR reported in mL/min/1.73 m^2; operative time reported in minutes; estimated blood loss reported in mL; tumor size reported in cm; MMEs reported in mg. SP-RANU: Single-port robot-assisted nephroureterectomy; IQR: interquartile range; BMI: body mass index; CKD: chronic kidney disease; ASA: American Society of Anesthesiologists; ECOG: Eastern Cooperative Oncology Group; eGFR: estimated glomerular filtration rate; LAA: lower anterior approach; LFA: lateral flank approach; MMEs: morphine milligram equivalents; POD: postoperative day.

series - the remaining four specimens removed exhibited low grade urothelial carcinoma. All cases of SP-RANU performed for oncologic purposes resulted in negative margins. No patients exhibited evidence of local oncologic recurrence at follow-up; however, the one patient with high-grade urothelial carcinoma experienced distant metastasis. This patient underwent immunotherapy and chemotherapy, with no evidence of cancer on most recent PET scan. In the setting of a short median follow-up duration, these oncologic findings should be interpreted cautiously and are primarily presented descriptively.

Postoperatively, the median hospital length of stay (LOS) following SP-RANU was 1.5 days (IQR 1-5). The median postoperative time with Foley catheter was 4 days (IQR 3-4). Two patients experienced post-operative Clavien-Dindo Grade II complications. One patient experienced a transient acute kidney injury (AKI) and postoperative ileus that resolved with conservative management. A second patient was noted postoperatively to be in atrial fibrillation with rapid ventricular response and was treated medically in the surgical ICU where he subsequently converted to sinus tachycardia. The patient was discharged the following morning, on post-operative day 1.

The median pre-operative creatinine was 1.1 mg/dL (IQR 0.9-1.2), median post-operative day one creatinine was 1.3 mg/dL (IQR 1.2-1.6), and median creatinine on day of discharge was 1.2 mg/dL (IQR 1.1-1.7). Median pre-operative Ce [estimated glomerular filtration rate (eGFR)] was 72 mL/min/1.73 m^2 (IQR 66.8-78), median post-operative day one eGFR was 57.5 mL/min/1.73 m^2 (IQR 45-67), and median eGFR on day of discharge was 65.5 mL/min/1.73 m^2 (IQR 41.5-70.8). There was a median reduction of eGFR between pre-operative and discharge values of 9 mL/min/1.73 m^2 (IQR 3.3-17).

Five patients required narcotics post-operatively while inpatient, and two patients were discharged without narcotic pain medication. The remaining four patients were discharged with multimodal pain management. The 30-day readmission rate was 33%.

DISCUSSION

This single-institution series demonstrates SP-RANU as both a safe and feasible surgical approach for patients undergoing radical NU. No intraoperative complications were observed, median estimated blood loss was 325 mL, and median LOS was 1.5 days, demonstrating promising early perioperative outcomes within the range of previously published robotic NU series[10]. SP-RANU demonstrated a safe peri-operative profile, with two Clavien-Dindo II events occurring, neither requiring reoperation. These findings align with feasibility and safety signals of prior SP series and implementation reports[5,9,11].

Within this series, perioperative profiles align with minimally invasive advantages seen with similar robotic platforms relative to open NU, including reduced transfusions, shorter hospitalizations and less pain while still preserving oncologic outcomes[2]. While this study does not directly compare SP-RANU with MP-RANU, the rate of intraoperative complications, operative times, estimated blood loss, and other intraoperative factors are consistent with MP-RANU series[2,12]. Taken together with prior SP reports, these findings support the technical feasibility of SP-RANU and suggest that acceptable early perioperative outcomes may be achievable in carefully selected patients.

From a technical standpoint, the variability in operative time (median 297 min; range 199-578 min) likely reflects an early learning curve and variability in case complexity. The SP requires additional surgical training to optimize efficiency as teams standardize port placement and instrument sequencing. In particular, the ability to complete bladder-cuff excision and upper-tract dissection within a single docking is a core SP advantage in NU cases. These platform characteristics may be most impactful in patients with significant prior abdominal surgery where retro-/extraperitoneal approaches reduce bowel manipulation, potentially lowering ileus risk and facilitating earlier discharge[1,5,9].

One possible advantage of SP-RANU is a minimized need for postoperative opioid pain management. With low inpatient postoperative opioid use [median morphine milligram equivalen (MME) 77 mg] and one patient requiring no inpatient opioid pain management at all, the SP approach was associated in this series with minimal postoperative pain burden for patients and less narcotic use, translating to faster patient recovery and shorter hospital stays. Additionally, two patients required no narcotic pain management at discharge, and those who did require narcotics utilized a median MME of 45 mg - supporting multimodal pain management as an adequate strategy for discharge pain management. Similarly, this series showed minimal difference between pre- and post-operative creatinine or eGFR in patients undergoing SP-RANU.

The long-term outcomes of our patients in this study are limited by the short follow-up duration and small sample size. Although no local recurrence was observed at most recent follow-up, definitive conclusions regarding oncologic equivalence, recurrence-free survival, metastasis-free survival, or long-term renal functional preservation cannot be made in the setting of this sample size. The patient with pathologic node positive disease at the time of NU experienced distant recurrence (left supraclavicular lymph node) and was treated with systemic therapy. Importantly, the heterogeneity in tumor stage, grade, and nodal status within this cohort suggests that oncologic outcomes may be influenced by underlying tumor biology in addition to surgical platform. These factors should be considered when interpreting early results. Of the two Clavien-Dindo Grade II events occurring, neither required reoperation. There were no documented long-term complications, supporting the overall safety profile of SP-RANU.

Strengths of this study include the breadth of data gathered in combination with the consistent technique and protocol coming from the single institution. This provides uniformity in data and lends credence to the safety, feasibility, and effectiveness of SP-RANU. Conversely, this study is limited by its small single-center sample size, which reduces generalizability. Additionally, the small sample size limits comparison between the two different surgical approaches used (LAA *vs.* LFA), for which further research is required. The biologic heterogeneity of included tumors further limits broad comparisons across cases. Selection bias presents an additional limitation. The SP approach was selected according to specific reasons including surgeon discretion, anatomy, and disease characteristics, potentially adding bias within the cohort toward favorable operative candidates. As a result, this bias may limit generalizability to broader UTUC populations. Although previously reported meta-analyses suggest robotic NU is comparable to open NU in terms of oncologic control, determining whether SP-RANU surpasses MP-RANU for intravesical recurrence, metastasis-free survival, and overall survival will require larger cohorts, longer follow-up, and uniform imaging surveillance[13].

Beyond surgical technique alone, modern UTUC management increasingly incorporates molecular heterogeneity, genomic alterations, and biomarker-driven therapeutic strategies. FGFR3 alterations have emerged as a clinically relevant marker in subsets of urothelial carcinoma and may influence future risk stratification and targeted therapeutic approaches[14,15]. Additionally, evolving urinary and circulating cell-free DNA (cfDNA) surveillance strategies may eventually help better postoperative monitoring and recurrent detection following NU[16,17]. While these translational approaches were beyond the scope of this surgical

series, future studies integrating molecular profiling with perioperative outcomes may further optimize patient selection and direct personalized management in SP-RANU.

In conclusion, SP-RANU offers a safe, feasible, minimally invasive surgical option for select patients requiring NU for both oncologic and benign indications. SP-RANU was associated in this early series with a less invasive approach with low rates of intraoperative complications, shortened length of hospital stay, and postoperative pain control with minimal use of opioid pain medications. The SP platform's ability to complete multi-quadrant tasks through a single docking access provides an effective and adaptable surgical approach while minimizing bowel manipulation and incision burden. These preliminary findings suggest that SP-RANU may offer promising early perioperative outcomes in carefully selected patients. However, definitive conclusions regarding oncologic equivalence or long-term cancer control cannot yet be established. As experience grows and technique refines, SP-RANU offers a promising surgical option within the NU landscape for patients who will benefit from the most minimally invasive technique.

DECLARATIONS

Authors' contributions

Made substantial contributions to the literature review, conception and design of the study, manuscript drafting, critical revision, manuscript preparation, and approved the final version for publication: Alli NK

Performed data analysis and interpretation, contributed to manuscript drafting, critically revised the work, and approved the final version for publication: Casey KW

Contributed to methodological detailing, critically revised the work, assisted with manuscript preparation, provided administrative/technical/material support, and approved the final version for publication: Langbo WA

Contributed to the literature review, initial search strategy, introduction drafting, and approved the final version for publication: Alli AHO

Assisted with data collection, contributed to manuscript review, and approved the final version for publication: Biasatti A

Contributed to the initial conception of the study idea, manuscript review, critical revision, supervision, and approved the final version for publication: Autorino R

Contributed to the conception of the study idea, manuscript review, critical revision, and approved the final version for publication: Vourganti S

Contributed to manuscript review, edits, data oversight, overall project supervision, and approved the final version for publication: Reisz PA

Availability of data and materials

The data presented in this study are available on request from the corresponding author due to patient privacy restrictions under HIPAA.

AI and AI-assisted tools statement

During the preparation of this manuscript, the AI tool ChatGPT (OpenAI, GPT-5.5, first tool version released 2022-11-30) was used to assist with the generation and refinement of the graphical abstract. This tool did not influence the study design, data collection, data analysis, data interpretation, or the scientific content of the manuscript. All authors take full responsibility for the accuracy, completeness, and final content of this manuscript.

Financial support and sponsorship

None.

Conflicts of interest

Autorino R is an Editorial Board Member of *Mini-invasive Surgery* and served as Guest Editor for the Special Topic "Single-Port Robotic Surgery in Urology: Current Applications and Future Perspectives". Autorino R was not involved in any stage of the editorial process for this manuscript, including reviewer selection,

manuscript handling, or final decision-making. The other authors declare that they have no conflicts of interest.

Ethical approval and consent to participate

This study was reviewed and granted an exemption from IRB review by the Institutional Review Board of Rush University Medical Center (FWA #: 00000482; ORA #: 22111001-IRB01) in accordance with 45 CFR 46.104(d)(4). Given the retrospective nature of the study and use of existing de-identified clinical data, the requirement for informed consent was waived. All study procedures were conducted in accordance with institutional guidelines and the ethical principles of the Declaration of Helsinki.

Consent for publication

Not applicable.

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