Robot-assisted radical nephroureterectomy for upper urinary tract tumor: initial experience with the use of novel surgical robot system, hinotori

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Background: The hinotori surgical robot system is a promising robotic platform that has been recently introduced into routine clinical practice. The aim of this study was to report our initial experience of robot-assisted radical nephroureterectomy (RANU) using hinotori.

Methods: This study included a total of eight patients with upper urinary tract tumor (UUTT) who underwent RANU using hinotori via the transperitoneal approach. In this series, nephrectomy was initially performed at the kidney direction stage followed by distal ureterectomy and bladder cuff excision at the bladder direction stage without repositioning of patient or port. Lymphadenectomy was performed at either stage.

Results: Median age, body mass index, and tumor diameter were 76 years, 21.7 kg/m^2, and 13 mm, respectively. Of eight patients, three were diagnosed with renal pelvic tumors and five with lower ureteral tumors. They underwent lymphadenectomy targeting the renal hilum plus para-aorta and the pelvis, respectively. All procedures in this series were completed without conversion to open surgery. Median operative time, time using the robotic system, estimated blood loss, and length of hospital stay were 230 minutes, 138 minutes, 23 mL, and 8 days, respectively. No major perioperative complication occurred. Pathological examinations of the tumors revealed seven urothelial carcinomas and one papilloma, the median number of resected lymph nodes was 13, and one patient was positive for both cancer margin and lymph node metastases.

Conclusions: Despite being a small case series, this is the first study characterizing RANU using the hinotori surgical robot system. RANU was efficaciously and safely performed, resulting in the achievement of favorable perioperative findings.

Keywords: Hinotori; perioperative outcomes; robot-assisted radical nephroureterectomy (RANU)

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Introduction

The recent introduction of robotic surgery into routine clinical practice has revolutionized minimally invasive surgery (MIS). It has become possible to markedly expand the indications of MIS in highly complex cases using a surgical robot system. The robotic system is characterized by various useful features, including articulated arms with multiple degrees of freedom, scale motion function to relieve physiological tremors, and 3-dimensional clear image on magnified visual field (1). In the field of urology MIS, robotic surgery has gained particularly rapid and wide acceptance as a promising alternative to laparoscopic surgery in the majority of major surgeries, including radical prostatectomy, partial nephrectomy, and radical cystectomy, and it has generally provided equivalent or even superior outcomes to other surgical approaches (2,3).

To date, the da Vinci surgical system (Intuitive Surgical Inc., Sunnyvale, CA, USA) has represented the leading platform for robotic surgery across the world; however, the recent adoption of this system has been slowed due to economical considerations. Accordingly, since the expiration of some relevant patents related to da Vinci in 2019, novel competitors with unique technical refinements have entered the surgical robot system market (4-8). Among them, the hinotori surgical robot system, launched by Medicaroid Corporation (Kobe, Japan) and co-funded by Sysmex Corporation and Kawasaki Heavy Industries

(Kobe, Japan), has been introduced into Japanese real-world clinical practice. This surgical robot has several unique and attractive characteristics that differentiate it from existing systems (8). Promising perioperative outcomes using hinotori have already been reported in a series of robot-assisted radical prostatectomies (RARP) and robot-assisted partial nephrectomies (RAPN) (8,9). However, there has not been any study focusing on robot-assisted radical nephroureterectomy (RANU) using hinotori. The present study describes our initial experience with RANU using hinotori without patient or port repositioning in order to characterize the feasibility of this platform for performing RANU for patients with upper urinary tract tumor (UUTT). We present this article in accordance with the STROBE reporting checklist (available at https://tcr.amegroups.com/article/view/10.21037/tcr-23-853/rc).

Methods

Patients

This study included a total of eight constitutive patients with UUTT who received RANU using hinotori between July 2022 and March 2023 at our institution. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional review board of Hamamatsu University School of Medicine (No. 21-090) and individual consent for this retrospective analysis was waived.

Evaluation

All data of the included patients with respect to clinicopathological and perioperative findings were obtained from their medical records at our hospital. The indication for RANU in this series was clinically non-metastatic UUTT. All patients preoperatively underwent appropriate examinations including computed tomography (CT) of the abdomen and chest, cystoscopy, and urinary cytology. In patients with radiological findings suspicious for UUTC but negative on urinary cytology, diagnostic ureteroscopy was additionally performed. The severity of perioperative complications was evaluated according to the Clavien-Dindo system (10), and major complications were defined as those corresponding to Clavien-Dindo ≥3.

Surgical procedure

RANU was conducted by three robotic surgeons, who

Highlight box

Key findings
- Robot-assisted radical nephroureterectomy (RANU) using the novel surgical robot system, hinotori, could provide favorable perioperative outcomes in patients with upper urinary tract tumor (UUTT).

What is known and what is new?
- RANU with the use of an existing platform (da Vinci) has been reported to enable the completion of the procedure in UUTT patients without patient or port repositioning.
- It was possible to complete RANU using hinotori using the same procedure as da Vinci. Perioperative outcomes in this series were similar to those in previous studies using da Vinci.

What is the implication, and what should change now?
- Considering the unique features of hinotori, such as more flexible movement of robotic arms in eight axes and software calibration of the trocar position without docking the arm, its use may have advantages due to the smooth maneuverability between the kidney and bladder regions during RANU.
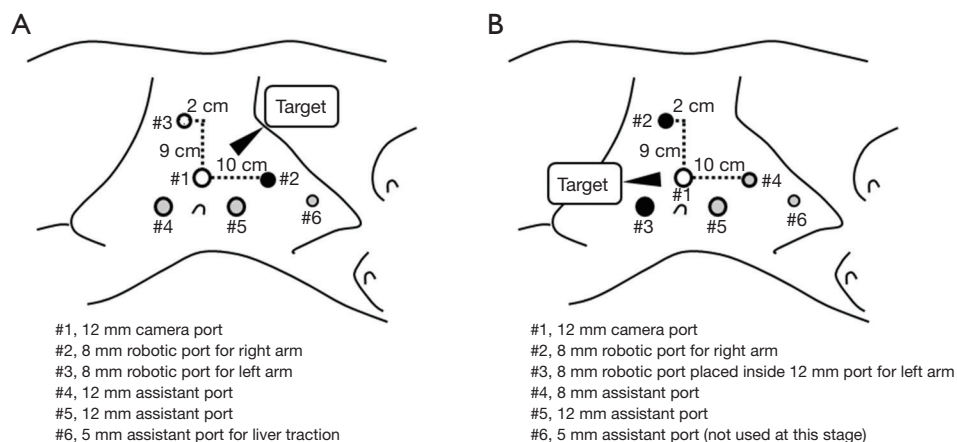

3524

Motoyama et al. Initial experience of RANU using hinotori

Figure 1 Trocar placement in cases undergoing robot-assisted right radical nephroureterectomy using hinotori. (A) Trocar placement at the kidney direction stage. (B) Trocar placement at the bladder direction stage.
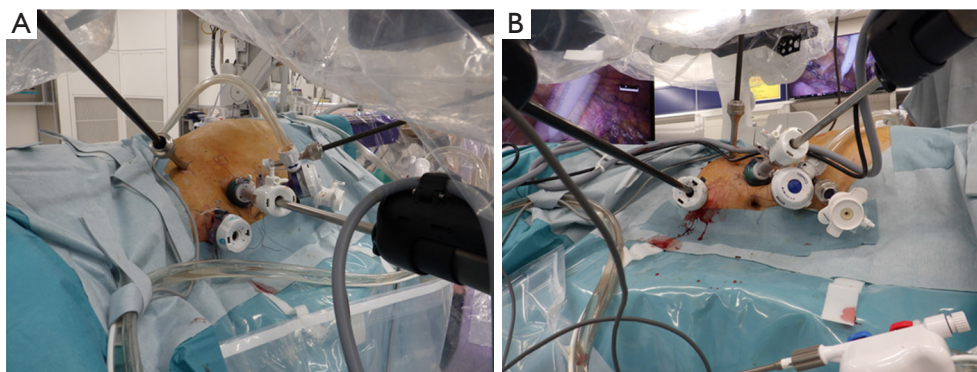

Figure 2 Intraoperative pictures in a case undergoing robot-assisted right radical nephroureterectomy using hinotori. The patient cart is docked to the patient at the kidney direction stage (A) and the bladder direction stage (B).

had been certified as proctors for robot-assisted surgery by the Japanese Society of Endourology and Robotics and performed at least >200 robotic surgeries as an operator prior to the involvement in RANU. All procedures were performed for patients in a modified flank position with the diseased side up through the trans-peritoneal approach. As presented in *Figure 1*, three trocars for the use of robotic arms and two or three trocars, including AirSeal iFS (CONMED Japan KK, Tokyo, Japan), for use by assistant surgeons were placed. The following instruments were used during RANU: monopolar curved scissors, bipolar fenestrated forceps, and needle holder. A vessel-sealing device was not used in this series. Lymph node dissection (LND) was conducted in all patients, and as its extent was determined based on the location of UUTT as previously described (11).

At the kidney direction stage wherein hinotori targeted the renal hilum (*Figures 1A,2A*), nephrectomy was performed in all patients as previously described (12,13), followed by the mobilization of ureter to the level of the bifurcation of common iliac vessels. LND targeting the renal hilum plus para-aorta was then added in patients with UUTT of the renal pelvis. Upon completion of the procedure at the kidney direction stage, all robotic arms were released, and reconfigured for the bladder direction stage wherein hinotori targeted the vesicoureteral junction (*Figures 1B,2B*) by maintaining the position of patient and port. After peeling off the ureter up to the bladder, the ureter was dissected from the bladder until the recognition of the tented bladder mucosa, and distal ureterectomy and bladder cuff excision were performed by cold cut using monopolar curved scissors, and cystotomy was closed by the

Table 1 Preoperative characteristics of patients who underwent robot-assisted nephroureterectomy using hinotori surgical robot system

No.	Age (years)	Sex	BMI (kg/m²)	ECOG-PS	DM	HT	Preoperative CKD	Abdominal surgery	Tumor location	Tumor side	Tumor size (mm)	TNM classification
1	70	Male	26	0	No	Yes	No	Yes	Renal pelvis	Left	11	cT1N0M0
2	78	Male	23.1	0	Yes	Yes	Yes	Yes	Lower ureter	Right	9	cT1N0M0
3	79	Male	21.8	0	No	Yes	Yes	No	Renal pelvis	Left	55	cT3N0M0
4	82	Male	22.2	0	No	Yes	Yes	No	Renal pelvis	Left	51	cT3N0M0
5	81	Male	21.5	1	No	Yes	Yes	No	Lower ureter	Left	16	cT1N0M0
6	51	Male	19.4	0	No	No	No	No	Lower ureter	Left	12	cT1N0M0
7	69	Male	20	0	No	Yes	Yes	No	Lower ureter	Right	13	cT1N0M0
8	74	Male	20.9	0	Yes	No	No	No	Lower ureter	Left	6	cT1N0M0
Overall[a]	76	–	21.7	–	–	–	–	–	–	–	13	–

[a], values are presented as median. BMI, body mass index; ECOG-PS, Eastern Cooperative Oncology Group Performance Status; DM, diabetes mellitus; HT, hypertension; CKD, chronic kidney disease; TNM, tumor, node, metastasis.

running barbed suture with 3-0 V-Loc (Medtronic, Tokyo, Japan). LND was then performed targeting the ipsilateral pelvis, including resection of the ipsilateral common iliac, external iliac, obturator and internal iliac nodes, in patients with UUTT of the lower ureter. The en bloc specimen was retrieved via an approximately 5 cm incision by lengthening the paraumbilical camera port.

Results

This study included a total of eight UUTT patients undergoing RANU using hinotori surgical robot system. Baseline clinical characteristics of these patients are presented in *Table 1*. The median age, body mass index, and tumor diameter were 76 years, 21.7 kg/m², and 13 mm, respectively. Three patients were diagnosed with renal pelvic tumor and five with lower ureteral tumor.

All of the eight patients received RANU using hinotori via the transperitoneal approach (*Table 2*). LND targeting the renal hilum plus para-aorta and the pelvis was performed in three renal pelvic and five lower ureteral tumors. All procedures in this series were completed as planned without conversion to open surgery. Median operative time, time using the robotic system, and estimated blood loss were 230 minutes, 138 minutes, and 23 mL, respectively. All patients did not experience major perioperative complication. The median length of hospital stay was 8 days. Final pathological examinations of the resected specimens showed that seven were urothelial carcinoma and one was papilloma, the median number of the dissected

lymph nodes was 13, and one patient was diagnosed as having positive findings on cancer margin and nodal involvement.

Discussion

In recent years, competition to develop new robotic platforms has intensified. Some have already been released and introduced into clinical practice (4-8). Of these, hinotori, launched by Medicaroid Corporation in 2019 as the first made-in-Japan surgical robot system, has several advantageous features that differentiate it from the existing system, da Vinci, as follows: (I) robotic arms that consist of eight axes enable more flexible movement and prevent them interfering with each other (*Figure 3*). (II) Software-based calibration of the trocar position without docking an arm with a trocar provides a sufficient space in a clean field and protects collisions among arms outside the body. (III) A 3D viewer mounted in the surgeon's cockpit makes it possible to relieve the fatigue of surgeons by flexible positioning (8). As the initial human surgery with the use of hinotori, RARP was successfully performed in 2020. Since then, the proportion of robotic surgeries performed using hinotori in Japan is gradually increasing, and favorable perioperative outcomes using hinotori were reported in two series of patients undergoing RARP and RAPN (8,9). Thus, the use of hinotori may also be suitable for RANU, which requires highly complex procedures (14-20); however, there are no previous studies of RANU using hinotori.

Radical nephroureterectomy with bladder cuff excision

Table 2 Perioperative outcomes of patients who underwent robot-assisted nephroureterectomy using hinotori surgical robot system

No.	Surgical approach	Area of lymph node dissection	Operative time (minutes)	Time using robotic system (minutes)	Estimated Blood loss (mL)	Blood translation	Open conversion	Postoperative major complication[b]	Resected tumor weight (g)	Length of hospital stay (day)	Histology	pT stage	Number of positive/resected lymph nodes	Positive cancer margin
1	Transperitoneal	Renal hilum/paraaorta	220	118	35	No	No	No	608	6	Urothelial carcinoma	pT1	0/31	No
2	Transperitoneal	Pelvis	270	206	12	No	No	No	402	6	Urothelial carcinoma	pT3	2/14	Yes
3	Transperitoneal	Renal hilum/paraaorta	210	131	50	No	No	No	520	9	Urothelial carcinoma	pT3	0/24	No
4	Transperitoneal	Renal hilum/paraaorta	230	137	50	No	No	No	326	12	Urothelial carcinoma	pT1	0/12	No
5	Transperitoneal	Pelvis	230	138	5	No	No	No	366	6	Urothelial carcinoma	pT1	0/18	No
6	Transperitoneal	Pelvis	239	143	34	No	No	No	180	8	Urothelial papilloma	–	0/7	–
7	Transperitoneal	Pelvis	250	163	1	No	No	No	288	8	Urothelial carcinoma	pT1	0/5	No
8	Transperitoneal	Pelvis	212	124	8	No	No	No	394	8	Urothelial carcinoma	pTis	0/12	No
Overall[a]	–	–	230	138	23	–	–	–	380	8	–	–	–	–

[a], values are presented as median; [b], corresponding to Clavien-Dindo grade ≥3.
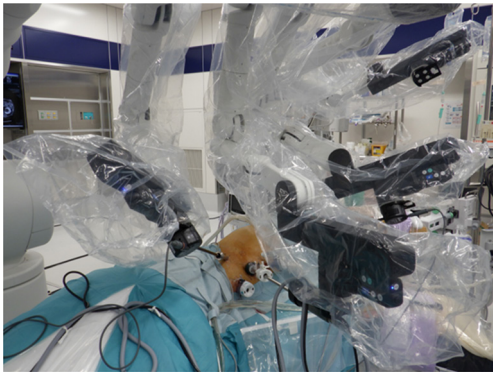
Figure 3 The picture of robotic arms of hinotori consisting of eight axes that enable more flexible movement and prevent them from interfering with each other. Software-based calibration of the trocar position without docking an arm with a trocar provides a sufficient space in a clean field and protects collisions among arms outside the body.

is regarded as the standard treatment for patients with UUTT. This procedure can be conducted by either an open or minimally invasive approach, including using a surgical robot system (14). Since the first report in 2006 (15) and subsequent studies introducing technical refinements (16-20), RANU has been increasingly adopted in real-world clinical practice. As a result, several studies have reported the advantages of RANU over other surgical approaches (21-23). Veccia *et al.* performed a systematic review and meta-analysis and reported that RANU could offer benefits as a minimally invasive approach without impairing oncological outcomes compared to open and laparoscopic nephroureterectomies (21). However, accumulating findings with respect to RANU are still limited to studies performed with da Vinci (15-23). The present study summarizes the perioperative findings of the first series of eight patients undergoing RANU using hinotori.

At our institution, RANU was performed in four UUTT patients using da Vinci prior to insurance coverage in April 2022, and thereafter eight UUTC patients underwent RANU using hinotori until March 2023. In the series of eight patients with the use of hinotori, RANU, including bladder cuff excision and LND, was completed in all patients without conversion to open surgery. Furthermore, by properly reconfiguring robotic arms from the kidney to bladder direction stage, it became possible to precisely operate in the upper abdomen and deep in the pelvis; thus, all procedures were accomplished without the requirement of patient or port repositioning. Favorable

perioperative outcomes were achieved including operative time, time using the robotic system, estimated blood loss, and incidence of major perioperative complications. Collectively, these findings suggest that RANU using hinotori is a useful alternative to conventional open and laparoscopic approaches.

It is of interest to compare perioperative outcomes in this series with those in patients undergoing RANU using da Vinci. The perioperative findings of the four patients who received RANU using da Vinci were as follows: operative time =211 minutes; time using the robotic system = 132 minutes; estimated blood loss =35 mL; major complications =0%; and length of hospital stay =10 days. There were no significant differences in the perioperative outcomes between the hinotori and da Vinci groups. Furthermore, the present outcomes using hinotori were equivalent or even superior to those in previous studies focusing on RANU using da Vinci (16-27). Morizane *et al.* reported the following perioperative outcomes in the report of first series of nine cases undergoing RANU using da Vinci in Japan: operative time =323 minutes; time using the robotic system =209 minutes; estimated blood loss =55 mL; major complications =0%; and length of hospital stay =12 days (16). Veccia *et al.* conducted a multicenter study that included 185 patients receiving RANU using da Vinci, and reported that operative time, estimated blood loss, incidence of major postoperative complications, and length of hospital stay were 216 minutes, 100 mL, 24.4%, and 3.5 days, respectively; however, LND was performed in only 45.9% of the included patients (24).

This study has several limitations. Firstly, it was a small retrospective case series containing only eight patients undergoing RANU using hinotori. Our findings will need to be confirmed by a future prospective assessment with more patients. In addition, prognostic outcomes based on long-term follow-up should also be evaluated for more comprehensive assessment of RANU using hinotori. Secondly, it may be difficult to compare the present findings with those in other studies due to the significant diversity of surgical techniques used, particularly studies that involved management of distal ureter. Thirdly, length of hospital stay in Japan is usually longer than that in Western countries regardless of procedure. This may be explained by the difference of social insurance systems rather than as a result of surgical stress; therefore, attention should be paid when interpreting findings related to this point. Fourthly, although RANU could be completed without re-docking with the use of da Vinci Xi (19), in the present study, it was

necessary to undock hinotori when moving from the kidney to bladder direction stage to determine the trocar position once again by software-based calibration. This difference may affect perioperative outcomes of RANU using hinotori.

Conclusions

This is the first report to describe the perioperative outcomes of RANU using the novel surgical robot system, hinotori. In this series containing eight UUTT patients, RANU, including bladder cuff excision and LND, could be safely completed as planned without repositioning of patient or port, resulting in the achievement of favorable perioperative outcomes. Further prospective studies with a larger sample size are necessary.

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Footnote

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Ethical Statement: The authors are 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. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by institutional review board of Hamamatsu University School of Medicine (No. 21-090) and individual consent for this retrospective analysis was waived.

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