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ORIGINAL ARTICLE

Initial experience of robot-assisted partial nephrectomy with Hugo™ RAS system: implications for surgical setting

Andrea Gallioli[1] · Alessandro Uleri[1] · Josep Maria Gaya[1] · Angelo Territo[1] · Julia Aumatell[1] · Paolo Verri[1] · Giuseppe Basile[1] · Sofia Fontanet[1] · Alessandro Tedde[1] · Pietro Diana[1] · Edgar Suquilanda[1] · Ferran Algaba[2] · Joan Palou[1] · Alberto Breda[1]

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Abstract

Purpose Hugo™ RAS system is one of the most promising new robotic platforms introduced in the field of urology. To date, no data have been provided on robot-assisted partial nephrectomy (RAPN) performed with Hugo™ RAS system. The aim of the study is to describe the setting and report the performance of the first series of RAPN performed with Hugo™ RAS system.

Methods Ten consecutive patients who underwent RAPN at our Institution between February and December 2022 were prospectively enrolled. All RAPN were performed transperitoneally with a modular four-arm configuration. The main outcome was to describe the operative room setting, trocar placement and the performance of this novel robotic platform. Pre, intra and post-operative, variables were recorded. A descriptive analysis was performed.

Results Seven patients underwent RAPN for right-side and three for left-side masses. Median tumor size and PADUA score were 3 (2.2–3.7) cm and 9 (8–9), respectively. Median docking and console time were 9.5 (9–14) and 138 (124–162) minutes, respectively. Median warm ischemia time was 13 (10–14) minutes, and one case was performed clamp-less. Median estimated blood loss was 90 (75–100) mL. One major complication (Clavien-Dindo 3a) occurred. No case of positive surgical margin was recorded.

Conclusion This is the first series to prove the feasibility of Hugo™ RAS system in the setting of RAPN. These preliminary results may help new adopters of this surgical platform to identify critical steps of robotic surgery with this platform and explore solutions before in-vivo surgery.

Keywords Renal cancer · Robotic surgery · Robot-assisted partial nephrectomy · Nephron sparing surgery · Medtronic Hugo RAS system

Introduction

Robotic-assisted surgery is expanding in a wide number of urologic procedures. Even though its efficiency is broadly recognized, the spread of robotic surgical platforms across the world has been slowed down by its costs. Therefore, the advent of new surgical platforms has been awaited with relevant interest in the urologic community [1]. In 2019 several relevant patents of robotic platforms expired. This event marked the end of the robotic monopoly by opening the doors to competitive commercialization, which may translate in an increased offer to health structures combined with a reduction in expected costs [2].

The novel Hugo™ RAS system (Medtronic, Minneapolis, MN, USA) has received CE (Conformité Européenne)

Andrea Gallioli and Alessandro Uleri have equally contributed to the manuscript.

✉ Alessandro Uleri
alessandrouleri@outlook.it

[1] Department of Urology, Fundació Puigvert, Autonomous University of Barcelona, Carrer de Cartagena, 350, 08025 Barcelona, Spain

[2] Department of Pathology, Fundació Puigvert, Autonomous University of Barcelona, Barcelona, Spain

mark approval for gynecological and urological procedures in adult patients at the beginning of 2022.

The aim of this study is to describe the first series of robot-assisted partial nephrectomies (RAPN) performed with Hugo™ RAS system, providing useful information about the surgical setting.

Material and methods

Population

All patients with a renal mass candidate to RAPN were eligible for the study. The patients were recruited according to the availability of the trained surgical team and the robotic platform. Data of patients who underwent RAPN at our Institution between February and December 2022 were collected. During this period, the surgical activity with this new platform stopped for 4 months due to a structural defect of the robotic scissors that caused a premature deterioration of the instruments. All patients had preoperative imaging and renal masses were classified according to PADUA nephrometry score [3]. This study was conducted in accordance with the principles of Good Clinical Practice and the Declaration of Helsinki, all patients signed an informed consent, and the study was approved by the internal ethic committee of the hospital.

Endpoints and variables

The primary endpoint of the study was to report the surgical setting of Hugo™ RAS system to perform RAPN. The secondary endpoint was to assess the feasibility of RAPN with this novel robotic platform and report the outcomes. Pre, intra and postoperative data were collected. Estimated glomerular filtration rate (eGFR) was calculated according to the Chronic Kidney Disease (CKD) Epidemiology Collaboration formula [4]. Post-operative complications were graded according to Clavien-Dindo classification [5]. We reported categorical variables as frequencies. Continuous variables were reported as medians and interquartile ranges (IQR). All statistical analyses were performed using R software Version 4.1.3 (R Foundation for Statistical Computing, Vienna, Austria).

Robot-assisted partial nephrectomy with Hugo™ RAS system

A video description of the platform, the surgical setting and surgical technique is available in Supplementary Video section.

Patient and trocars positioning

Patients were positioned in full flank position with a 60° angle between the patient and the bed.

In case of left RAPN, an 11 mm trocar for the endoscope was placed 5 cm under the ribs' margin on the mid-clavicular line. Then, two 8 mm robotic trocars were placed on the pararectal line, maintaining 8 cm from the endoscope trocar. An 8 mm trocar for the fourth arm is placed 2 cm above the mid-clavicular line, 8 cm far from the right-hand trocar. A 12 mm trocar for the assistant was placed under the endoscope trocar (Fig. 1A). A 2 cm distance was maintained between trocars and bony prominences. In case of right RAPN, a specular scheme of trocar placement was adopted, maintaining 8 cm between robotic trocars and 2 cm between trocars and bony prominences (Fig. 2A). An additional 5 mm port for the assistant was placed cranially to the right arm trocar for liver retraction.

Carts positioning

In case of left RAPN (Fig. 1B), the cranial cart was the first arm to be connected and was placed back to the patient's head in 30° tilted-down position and a docking angle of 45°. Then, the endoscope cart was placed just back to the patient in 30° tilted-down position with 90° docking angle. Fourth arm cart was placed behind patient's legs in 30° tilted-down position and 135° docking angle. Finally, surgeon right-hand cart was placed in front of patient's legs with maximum tilt-up and 215° docking angle. All the carts were placed at a 45-60 cm distance from the operative table. In case of a right RAPN the carts positioning scheme was specular (Fig. 2B).

Surgical technique

All procedures were performed by a single expert (> 200 cases) robotic surgeon (A.B.). All members of the surgical team received the official training by Medtronic.

All surgeries were performed with transperitoneal approach, following the steps recently identified and approved by Delphi consensus group [6]: bowel (and spleen on the left) mobilization, identification of the ureter and gonadal vein, isolation of renal vessels, isolation from the peri-renal fat and mobilization of the kidney up to complete exposure of the renal mass and achievement of an adequate working space, renal artery clamp (not in case of zero-ischemia technique), enucleation or enucleoresection of the lesion, renorraphy (one or two layers depending on the endophytic development of the lesion; not in the fifth case in which a suture-less technique was employed), unclamping (in case of early unclamping, this step is performed before the outer layer of the suture) and Gerota's fascia closure. All the surgeries were performed

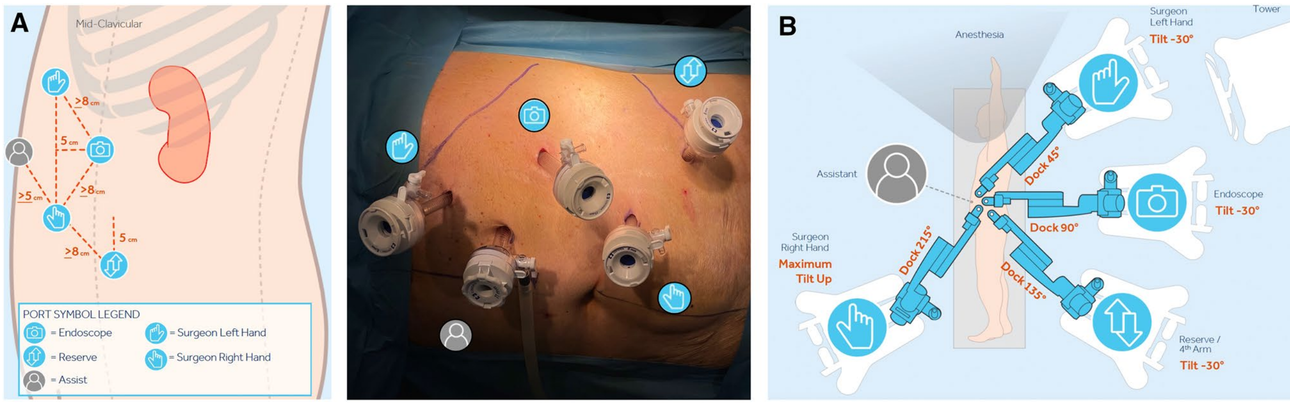

Fig. 1 Trocars placement (**A**), operating room setting and docking angles of the robotic arms (**B**) in case of left robot-assisted partial nephrectomy with Hugo™ RAS system. **A** A 11 mm trocar for the endoscope was placed 5 cm under the ribs' margin on the mid-clavicular line. Then two 8 mm robotic trocars were placed on the pararectal line, maintaining 8 cm from the endoscope trocar. An 8 mm trocar for the fourth arm is placed 2 cm above the mid-clavicular line, 8 cm far from the right-hand trocar. A 12 mm trocar for the assistant is placed under the endoscope trocar. A 2 cm distance was maintained between trocars and bony prominences. **B** Surgeon left hand cart was the first arm to be connected and was placed back to the patient's head in a 30° tilted-down position and a 45° docking angle. Then the endoscope cart was placed just back to the patient in a 30° tilted-down position with a 90° docking angle. Fourth arm cart was placed down to the endoscope, behind patient's legs in a 30° tilted down position and a 135° docking angle. Finally, surgeon right hand cart was placed in front of patient's legs with maximum tilt-up and a 215° docking angle

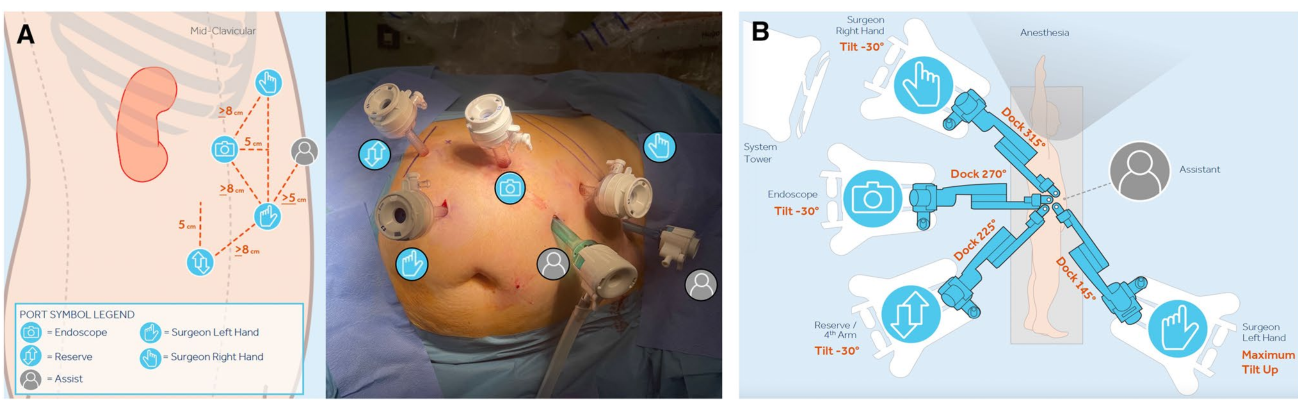

Fig. 2 Trocars placement (**A**), operating room setting and docking angles of the robotic arms (**B**) in case of right robot-assisted partial nephrectomy with Hugo™ RAS system. **A** A 11 mm trocar for the endoscope was placed 5 cm under the ribs' margin on the mid-clavicular line. Then two 8 mm robotic trocars were placed on the pararectal line, maintaining 8 cm from the endoscope trocar. An 8 mm trocar for the fourth arm is placed 2 cm above the mid-clavicular line, 8 cm far from the right-hand trocar. A 12 mm trocar for the assistant is placed under the endoscope trocar. A 2 cm distance was maintained between trocars and bony prominences. An additional 5 mm port for the assistant was placed cranially to the right arm trocar for liver retraction. **B** Surgeon right hand cart was the first arm to be connected and was placed back to the patient's head in a 30° tilted-down position and a 315° docking angle. Then, the endoscope cart was placed just back to the patient in a 30° tilted-down position with a 270° docking angle. Fourth arm cart was placed down to the endoscope, behind patient's legs in a 30° tilted-down position and a 225° docking angle. Finally, surgeon left hand cart was placed in front of patient's legs with maximum tilt-up and a 145° docking angle

using a Cadiere forceps in the 4th arm, a fenestrated or a Maryland bipolar forceps in the left-hand arm and a monopolar scissor in the right-hand arm. For suturing, a large needle driver was employed in the right-hand arm (Supplementary Fig. 1).

Results

Ten patients were submitted to RAPN with Hugo™ RAS system. Out of them, seven and three patients underwent

Table 1 Pre, intra and post-operative individual features of patients submitted to robot-assisted partial nephrectomy with Hugo RAS™ system

Patient	1	2	3	4*	5	6	7	8	9	10
Age (years)	60	42	76	78	87	67	73	69	44	62
Gender	Male	Male	Male	Male	Female	Female	Female	Male	Male	Female
Pre-op eGFR (ml/min)	103	95	69	78	38	95	73	91	105	97
Lesion size (cm)	4.3	2.6	3.8	6.1	3.2	2.0	2.9	3.0	2.0	1.3
Side	Left	Right	Left	Right	Right	Right	Right	Right	Left	Right
PADUA score	9	9	9	12	8	7	9	8	7	9
Docking time (min)	25	10	9	15	18	7	9	9	10	9
Operative time (min)	136	150	180	190	166	80	120	115	140	135
WIT (min)	18	14	16	13	0	5	13	17	13	10
EBL (ml)	70	200	100	100	95	90	65	90	150	50
Post-op complication	–	–	Pneumonia (CD 2)	Pseudoaneurysm (CD 3a)	Anemia (CD 2)	–	–	–	–	–
Post-op eGFR (ml/min)	99	75	64	65	40	98	74	89	108	95
Length of stay (days)	3	3	6	13	7	4	4	4	3	3
Histology (pT stage)	Papillary HG (pT3a)	Oncocytoma	Clear cell (pT1a)	Oncocytoma	Oncocytoma	Angiomyolipoma	Oncocytoma	Clear cell (pT1a)	Papillary LG (pT1a)	Papillary LG (pT1a)
PSM	0	–	0	–	–	–	–	0	0	0

eGFR estimated glomerular filtration rate, *WIT* Warm ischemia time, *EBL* Estimated blood loss, *CD* Clavien-Dindo, *HG* High-grade, *LG* Low-grade, *PSM* Positive surgical margin

*Converted to laparoscopic partial nephrectomy

RAPN for a right and left renal mass, respectively. The individual features of each patients are listed in Table 1. The surgical procedures are described in Supplementary Video. Six patients were male and median age was 68 (61–75) years. Median lesion size was 3 (2.2–3.7) cm with a PADUA score of 9(8–9). Median console time was 138 (124–162) minutes with a median docking time of 9.5 (9–14) minutes. Median estimated blood loss was 90 (75–100) mL, and the median warm ischemia time was 13 (10–14) minutes with one case performed clamp-less. One case of conversion to laparoscopic partial nephrectomy was reported. This was a right RAPN of a 6 cm renal mass (PADUA score 12) where the combination of a suboptimal trocars' placement and hepatomegaly, caused continuous collisions between the robotic arms for which a decision to convert to laparoscopic partial nephrectomy was taken. This patient subsequently developed a bleeding due to a pseudoaneurysm requiring selective arterial embolization on post-operative day 3 as the only major postoperative complication (Clavien-Dindo 3a) of the series. No other intraoperative complications occurred in our series. Median length of stay was 4 (3–6) days. No case of positive surgical margin was recorded.

Discussion

Recently, new robotic platforms have been released and involved in clinical trials covering different surgical specialties [7]. Hugo™ RAS system has been proven to be one of the most promising robotic platforms with a large spread in several robotic centers.

This system consists of an open console with a high-definition monitor (three-dimensionality is achieved through dedicated glasses) and "pistol-like" hand-controllers (Fig. 3). The wrist rotation may be doubled with a maximum range of 529° to facilitate the movements of the needle-driver especially during renorraphy. The open console eases direct communication with operating room staff and decreases the feeling of isolation of closed consoles. Moreover, the open console may allow rapid adaptation to robotic surgery by laparoscopists, who are not used to operate in closed consoles. So far, this platform lacks a system to integrate images from different sources like ultrasound images or tridimensional reconstructions, even if the open console allows a quick consultation of external devices.

The endoscopic vision is provided by a Karl-Storz 3D Tipcam S™ laparoscopic camera (Karl-Storz SE&Co. KG, Tuttlingen, Germany). To date an indocyanine green-guided near-infrared fluorescence technology is not yet available on this platform.

The system is modular and consists of four independent arm carts allowing a three- or four-arm configuration for surgery. The modularity of the Hugo™ RAS system allows different setups upon preferences or necessities as in case of different size or shape of operating rooms. But this could also represent a disadvantage because the four separate carts require usually more storage space than a single cart platform.

The performances of Hugo™ RAS system have already been assessed in some urological procedures, showing a short learning curve in experienced robotic surgeons [8–10]. The feasibility of robot-assisted radical prostatectomy (RARP) was assessed on cadavers allowing the setting of the robotic platform to be tested [11]. Recently Bravi et al.

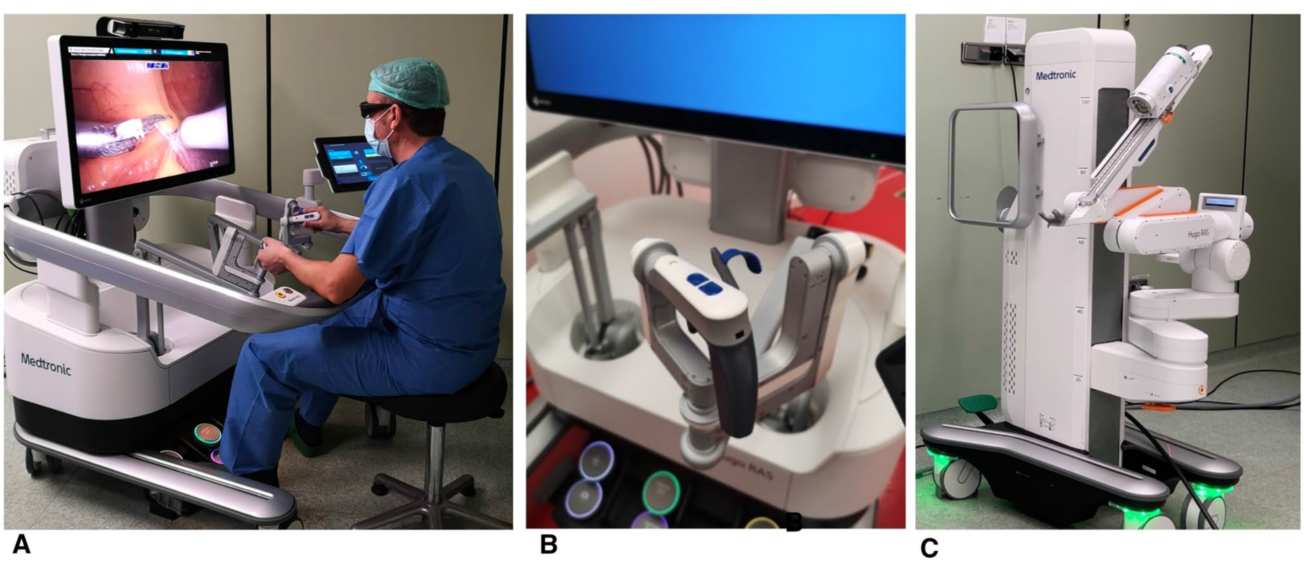

Fig. 3 Open console (**A**), "pistol-like" hand-controllers (**B**) and modular robotic arm cart (**C**) of Hugo^{TM} RAS system

published the first in-vivo series of five RARPs performed with Hugo™ RAS system, assessing the safety and versatility of this robotic platform [12].

To date only one series of three robot-assisted nephrectomies (one radical and two simple) was published by Ragavan et al. demonstrating the setting of this robotic platform in renal surgery and showed good results in terms of feasibility and safety [13].

This study aim was to provide a standardized operative room and docking setting to approach RAPN with Hugo™ RAS system. Every deviation from the trocars and carts placement, presented before, needs to be carefully tested to avoid technical issues. Notably, the only case in our series requiring conversion to laparoscopy was performed placing the trocars too laterally than the standard position. This prevented a correct docking angle of the robotic arms and consequentially led to continue arm clashing. Excluding this case, all RAPNs were performed without experiencing any issue. Therefore, we strongly recommend ex-vivo training to tailor the cart positioning and docking to the characteristics of the operating room and the usual setting of each Center.

This study is not devoid of limitations. First the number of procedures performed is limited. Furthermore, the procedures were performed by a single experienced surgeon and the results may be not reproduced by naïve surgeons.

The relatively low number of patients included during 10 months could suggest a careful selection of the cases. Actually, the cases were selected according to the availability of the surgeon and the robotic platform, currently employed for other surgeries (cystectomy, prostatectomy, nephrectomy and ureteral reimplantation). Moreover, in our Institution around 50% of partial nephrectomies (50–60 cases per year) are performed laparoscopically, while the others may be performed with Hugo™ RAS and Intuitive platforms.

Within these limitations, our study provides insights on the surgical setting and the feasibility of RAPN with Hugo™ RAS, that may be crucial to make the first steps with this novel robotic platform.

Conclusions

This is the first series to prove the feasibility of Hugo™ RAS system in the setting of RAPN. These preliminary results may help new adopters of this surgical platform to identify critical steps of robotic surgery with Hugo™ RAS system and explore solutions before in-vivo surgery.

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Author contributions AG: manuscript writing/editing, AU: data analysis, data collection or management, manuscript writing/editing, JMG: manuscript writing/editing, AT: manuscript writing/editing, JA: data collection or management, PV: data collection or management, GB: data collection or management, SF: data collection or management, AT: data collection or management, PD: data collection or management, ES: data collection or management, FA: data collection or management, JP: protocol/project development, AB: protocol/project development, manuscript writing/editing.

Data availability The dataset generated during and/or analysed during the current study is available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have nothing to disclose.

Research involving human participants and/or animals All analysis performed involving human participants were in accordance with 1964 Helsinki declaration and its later amendments.

Consent to participate All patients signed an informed consent agreeing to supply their anonymous information for research purposes.

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