Robotic-assisted partial nephrectomy using the Hugo™ robotic-assisted surgery platform: Initial experience and insights

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Cite as: Bobrowski A, Wu W, Angeles C, et al. Robotic-assisted partial nephrectomy using the Hugo™ robotic-assisted surgery platform: Initial experience and insights. *Can Urol Assoc J* 2024 December 9; Epub ahead of print. http://dx.doi.org/10.5489/cuaj.8951

Published online December 9, 2024

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ABSTRACT

Introduction: Robotic-assisted surgery (RAS) is a vital modality in the armamentarium of minimally invasive surgeons. The Hugo™ RAS system (Medtronic®) is one of the newest platforms on the market and has little surgical outcomes data. We describe our early experience performing robotic-assisted partial nephrectomy (RAPNx) with the Hugo RAS platform.
Methods: We conducted a retrospective review of patients who underwent a RAPNx with the Hugo RAS platform between April and December 2023 at the University Health Network in Toronto, ON. One surgeon performed all procedures using a three-arm transperitoneal approach. Anesthetic, operative, and pathologic reports were assessed to collect pre-, intra- and postoperative variables.
Results: Eleven patients were included. The mean age was 51 years, 45.0% were female, and 63.6% had a right-sided mass. Mean tumor size was 2.9 cm. Mean warm ischemia time was 18.9 min (standard deviation [SD] 7.12) and mean estimated blood loss was 179 mL (SD 63.6). Mean robot docking time was 232 seconds (SD 106.5), mean total console time was 93 minutes (SD 21.4), and mean total operative time was 165.6 minutes (SD 34.1). There were no intraoperative complications. On pathology review, most tumors were a clear cell variant (72.7%) and staged pT1a (81.8%). All margins were negative. One patient sustained a port site infection.
Conclusions: This is the first North American case series using the Hugo RAS platform for RAPNx. Our findings underscore that the platform is safe and effective for performing RAPNx with comparable outcomes to other robotic platforms.

INTRODUCTION

Since the approval of the da Vinci® surgical system (Intuitive Surgical®; Sunnyvale, CA, USA) by the Food and Drug Administration in 2000, robotic-assisted surgery (RAS) has become a vital modality in the minimally-invasive surgery armamentarium.[1] While laparoscopic surgery was introduced in the 1980s, the inability to articulate instruments posed a major challenge for intracorporeal suturing, which consequently posed a significant learning curve and hindered widespread adoption. Robotic platforms democratized minimally-invasive surgery by improving dexterity with articulating wrist technology, enhancing ergonomics, providing three-dimensional binocular imagery, and eliminating surgeon tremor.[1,2] By 2023, more than 60 000 surgeons have been trained on the da Vinci® and more than 12 million surgeries have been performed worldwide.[3] However, concerns pertaining to system financing, as well as limited evidence supporting added benefit, have slowed widespread adoption of robotic surgical systems across many healthcare jurisdictions.[4,5]

Nonetheless, robotic-assisted partial nephrectomy (RAPNx) has been hailed as "*the new gold standard for nephron sparing surgery*".[6] According to various guidelines, partial nephrectomy is the standard of care for small renal masses, bilateral renal tumors, and lesions in solitary kidneys as a means of preserving renal function and decreasing post-operative morbidity compared to radical nephrectomy.[7-9]

Laparoscopic partial nephrectomy is a complex procedure associated with a steep learning curve, thereby requiring significant skill. The technical difficulty associated with this procedure has led to longer documented warm ischemia time (WIT) and limited uptake.[10-16] The increased precision of RAS platforms allows for complex extirpative and reconstructive procedures to be carried out in a minimally invasive fashion. While no randomized control trials have shown added benefit of RAPNx to open and laparoscopic approaches, several studies have demonstrated the ability of RAPNx in achieving the *Trifecta* outcomes for simple and complex tumors, as well as solitary kidneys.[10-15] A systematic review that investigated differences between RAPNx and laparoscopic partial nephrectomy, and which included 8 studies and a total of 2705 cases, found RAPNx to have lower WIT and total surgical time without an increase in serious surgical complications.[16]

Several patents of RAS platforms expired in 2019, leading to commercialization of new systems. The Hugo™ RAS system (Medtronic®; Minneapolis, MN, USA) is one the most prominent platforms to reach the market. Since its first use in a robotic-assisted radical prostatectomy in Chile in 2021, it has received a Health Canada license and Conformité Européenne approval for use in gynecologic and urologic procedures.[17,18] There is little comprehensive clinical data pertaining to the surgical outcomes of this system. The aims of this study are to describe our early experience performing RAPNx with the Hugo™ RAS system and to provide related clinical insights.

METHODS

Population and study design

We conducted a retrospective review of all patients aged ≥18 years old who underwent a RAPNx with the Hugo™ RAS platform at the University Health Network (UHN) with a minimum follow-up of 30 days. Patients had pre-operative imaging of their renal masses either at our institution or externally. Detailed pre-operative counseling was conducted, and informed consent was completed prior to all surgeries. This study was approved by the Research Ethics Board of the UHN (CAPCR Study ID: 22-5442).

Endpoints and variables

The primary endpoint of this study was to assess the feasibility of RAPNx performance using the Hugo™ RAS platform. Within this endpoint, we sought to explore operative outcomes such as docking, operative and console time, estimated blood loss (EBL), WIT, and intra-operative complications. The post-operative course of these patients was explored, including post-operative complications (graded according to the Clavien-Dindo classification), length of hospital stay (LOS), as well as visits to the emergency department (ED) and hospital admissions within 30-days of the procedure. Anesthetic, operative and pathologic reports for each patient were assessed to collect pre-, intra-, and post-operative variables. Analyses were conducted using Microsoft Excel (Microsoft; Richmond, WA, USA).

Partial nephrectomy with the Hugo™ RAS

All procedures were performed by one experienced surgeon (JYL) using a 3-arm transperitoneal approach. The Medtronic® setup guide was used for port placement utilized by the surgeon (Figure 1).

For the procedures described herein, in conformity with the surgeon's usual practice, patients were positioned in a lateral decubitus position approximately 75^{o} to the surgical bed with slight flexion (15 - 30 ^{o}) of the bed. Pneumoperitoneum was established using a Veress needle.

Access to the peritoneal cavity was achieved with an 11 mm dilating camera port, placed under direct vision using the 10 mm Storz endoscope that comes with the Hugo™ RAS platform. Two 8 mm robotic trocars were then placed approximately at the pararectus line, 8 - 10 cm from the endoscope port. A 12 mm assistant port was placed near the umbilicus, while an additional 5 mm trocar was placed for liver retraction for right-sided RAPNx (Figure 2). Moreover, an additional 5 mm assistant port was used, as needed. With all ports in place, arm carts were brought in for docking at predetermined angles (Figure 1).

Patients were selected based on tumour location amenable to a transperitoneal approach. Surgical technique was like other RAPNx procedures performed. All surgeries were performed with monopolar curved shears in the right arm and bipolar fenestrated graspers in the left arm. For suturing, the right arm instrument was exchanged for a large needle driver. Artery-only clamping was used for all cases. Renorraphy was performed using running barbed sutures to oversew the resection bed and, when needed, capsular sutures (sliding clip technique) were used

concurrently. Hemostatic agents were used as needed. A fourth reserve arm with Cadiere forceps could have been employed; however, it was not used in any of the procedures. Jackson-Pratt drains were only placed on an *ad hoc* basis in cases involving significant resection into the urinary collecting system. Post-operative care followed standardized institutional ERAS pathways used for all RAPNx patients.

RESULTS

Eleven RAPNx were performed with the Hugo™ RAS platform between April – December 2023. Pre-operative patient characteristics are outlined in Table 1. Six patients (54.5%) were male, and the median age of our cohort was 58 years (IQR: 18). All procedures involved a single tumor, mean tumor size was 2.9 cm, and 63.6% of tumors were right-sided. One patient had a solitary kidney, and another had polycystic kidney disease.

Mean total console time was 93 min (SD: 21.4), while mean robot docking time was 232 s (SD: 106.5). Mean total skin-to-skin OR time was 165.6 min (SD: 34.1). All procedures were performed with clamping only the artery with a mean EBL of 179 mL (SD: 63.6). Mean warm ischemia time was 18.9 min (SD: 7.12). None of the cases were converted to an open or to a radical nephrectomy. Following the initial 3 procedures, trainees (residents and fellows) were involved in all cases, like any other RAPNx performed at UHN. There were no intra-operative complications in this series. Intra-operative variables are outlined in Table 2.

Post-operative outcomes and pathologic variables are outlined in Tables 3 and 4, respectively. Mean length of hospital stay was 2 days (SD: 0.83). Only one post-operative complication was observed in a single case: a wound infection from a laparoscopic port site incision, which was treated with antibiotics (Clavien-Dindo Grade II). All tumours were renal cell carcinoma with the vast majority staged as pT1a (90.9%) and being a clear cell variant (72.7%). Finally, all cases had negative margins.

DISCUSSION

For the past two decades, surgeons in North America have performed RAS using the da Vinci® surgical system. With the introduction of new RAS platforms, we hope to see an increase in competitive market forces that would drive innovation and help democratize access to advanced technologies. The Hugo™ RAS platform has thus far been successfully employed in radical and simple prostatectomy, partial nephrectomy, radical and simple nephrectomy, ureterolithotomy, ureteral reimplant, adrenalectomy, and pyeloplasty.[19]

The Hugo™ RAS system is novel in its design. It is composed of an open console with up to 4 independent arm carts that allows for a wide range of configurations based on surgeon preference, target anatomy and body habitus. The arm carts are operated by 2 arm-controllers with a pistol-like grip and footswitches that alternate between the camera, reserve arm, and energy source.[18] Each arm cart has 6 joints for greater range of motion as well as a wrist articulation multiplier, which offers 520º of rotational range for more accessible intracorporeal suturing. Additionally, the surgical tower can accommodate both robotic-assisted and

laparoscopic surgical approaches, facilitating easier transition if conversion is required. The surgeon operates with 3D glasses equipped with head tracking technology as a safety feature to prevent energy misfire or inadvertent activation of instruments.

Despite the difference in interface, skills of an experienced robotic surgeon have been shown to be transferrable between the da Vinci® and Hugo™ RAS platforms for robot-assisted radical prostatectomy without compromising patient safety or oncologic efficacy.[20] Similarly, a comparative analysis of robot-assisted simple prostatectomy utilizing the da Vinci® and Hugo™ RAS system did not demonstrate any differences in console or total operative time, nor in peri-operative or functional outcomes.[21] A non-randomized study comparing robot-assisted radical prostatectomy on the da Vinci® and Hugo™ RAS systems found no significant differences in console or operative time. While the docking times of the Hugo™ RAS arm carts was longer, the authors noted that the arm carts provided for better flexibility and more working space for the bedside assistant.[18,22]

Our study, the first North American series, demonstrates that the Hugo™ RAS system is an effective and safe platform for performing RAPNx with outcomes comparable to published literature using the da Vinci® surgical system.[23,24] Also, our outcomes are comparable to other early experiences of RAPNx performed with the Hugo™ RAS platform. To our knowledge, there are currently three European studies that have examined the use of the Hugo™ RAS platform in RAPNx.[25-27] Chiergo et al. published a prospective series of 10 patients who underwent transperitoneal or retroperitoneal RAPNx.[25] Nine cases consisted of stage T1 tumors with a median size of 2.75 cm. Docking, console, and operative times were longer than what was reported in our series. While no intra-operative complications were reported, post-operatively, 1 patient experienced chylous ascites, while another 2 developed pneumothoraxes. There was only 1 positive margin. Another study by Gallioli et al. reported on 10 consecutive patients who underwent transperitoneal RAPNx utilizing the Hugo™ RAS platform in a 4-arm configuration.[26] Median tumor size was 3 cm with a PUDUA score of 9. One case was clampless. While docking and console time were longer in this series compared to our results, the reported WIT was shorter. One case required conversion to laparoscopy, and later required selective arterial embolization to manage a pseudoaneurysm. No positive margins were reported. Lastly, Prata et al. described clampless RAPNx on 7 patients using a 3-arm configuration.[27] All cases involved cT1 tumors measuring 2.6 cm. Median RENAL score was 5. The median EBL was 200cc with no additional port placement or arm clashes reported. There were no intra- or post-operative complications. No positive margins were reported.

The novel design and functional elements of the Hugo™ RAS platform deserves some discussion. The open console design promotes improved communication with the surgical team by allowing the surgeon to be a part of the operating room environment and allows multiple observers to view the surgical field in 3D when seated behind the surgeon. Moreover, certain ergonomic benefits such as a more comfortable and flexible seating position associated with the open console design merit empirical verification. The individual arm cart design allows for more

individualized port placement based on patient body habitus. The levered design also allows for an impressive range of motion or excursion of each arm, particularly in the retrograde direction.

In spite of these benefits, a discussion of the platform's challenges is also warranted. First, since there is no second "teaching" console, swapping between surgeon and trainee requires more time and movement within the operating room. Second, there is a built-in safety feature when activating the energy pedals that may require an adjustment period for experienced robotic surgeons used to the da Vinci® platform. Third, the new pistol-grip controls offer a different hand position than robotic surgeons are accustomed to. In our experience, decreased rotational range of motion was evident (e.g., the surgeon was unable to rotate both wrist and fingers concurrently). The impact of the pistol-grip controls, especially on surgeons with very small or large hands, warrants investigation. Fourth, the longer and taller arm profile requires careful positioning of the ports to reduce collisions and requires the bedside assistant to navigate the movements of the longer arms more vigilantly. We found that for RAPNx, raising the height of the patient bed further from the floor allowed the assistant to be positioned somewhat below the movement of the arms, thus reducing the risk of collision. With this adaptation, we found that raising the height and changing the tilt angles of each arm facilitated better range of motion. Fifth, the multi-levered design of the arms results in slightly less visibility of the upper limits of the surgical field, when the arms are in their most open/stretched position. While most of the action during RAPNx is in front or below the horizon, the more laterally placed camera port seems to provide more advantageous viewing of the entire surgical field. Use of the 0 º rather than the 30 º lens also helped in this matter, as well as providing more space for the bedside assistant. Optimal port placement, tilt, and docking angles based on tumour location and patient body habitus still warrant further study.

Notwithstanding the valuable contribution of this study, some limitations warrant mentioning. This series is based on a small sample of non-randomly selected patients; therefore, our findings require further validation. As our study reports an initial experience with the Hugo™ RAS platform, one would expect improved performance metrics on balance with more surgical cases. Additionally, all cases were performed by one expert robotic surgeon; therefore, our results may lack generalizability. Nonetheless, our early experience suggests that the Hugo™ RAS system is a safe and effective tool for RAPNx. The functionality was very similar to the da Vinci® surgical system with a minimal learning curve for an experienced robotic surgeon.

CONCLUSIONS

Our single surgeon case series contributes to the accumulating body of evidence that the Hugo™ RAS platform is a safe and effective tool for performing RAPNx with comparable outcomes to other robotic platforms. The learning curve for experienced robotic surgeons is likely minimal. Prospective studies with larger samples should aim to validate our findings, and future research should systematically compare the Hugo™ RAS to other robotic platforms, especially in the context of urologic surgery. The addition of this promising, new RAS platform will hopefully propel further innovation and increase access to robotic surgery.

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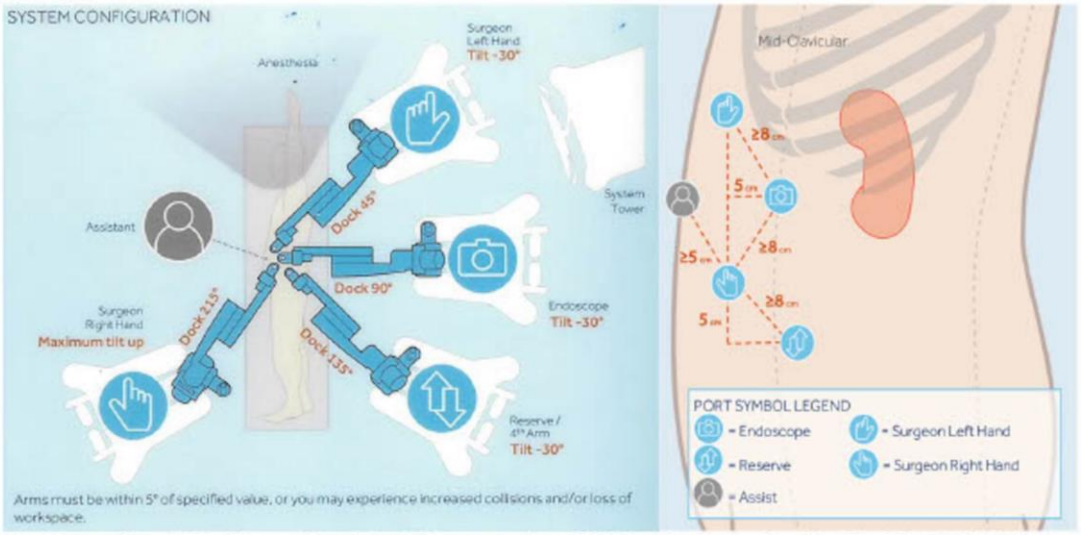
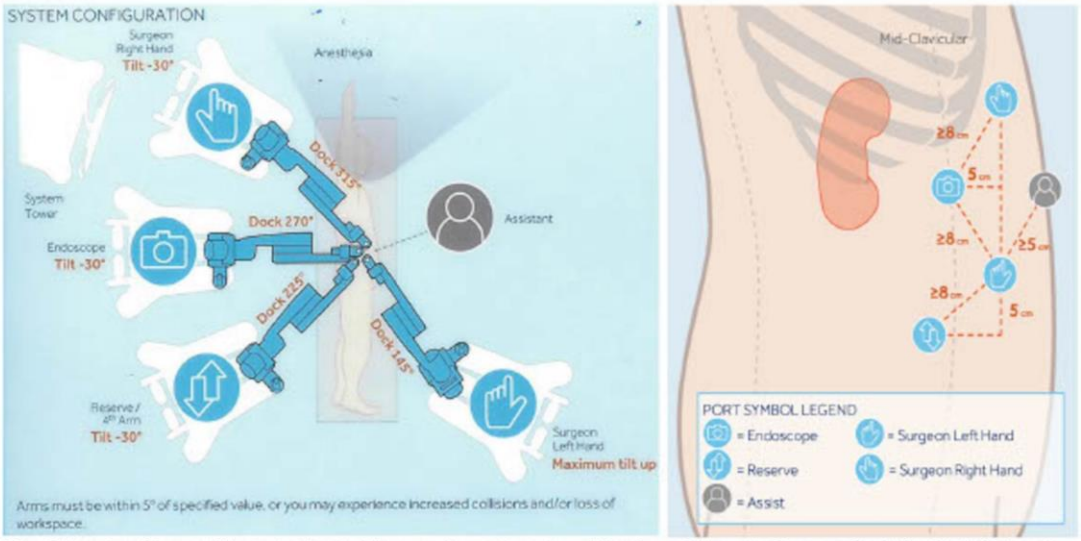
FIGURES AND TABLES

Figure 1. Templates for RAPNx port placement.

1a. Four-Arm Configuration Port Placement and Robotic Arm Angles for Left-Sided RAPNx



1b. Four-Arm Configuration Port Placement and Robotic Arm Angles for Right-Sided RAPNx



The following figures illustrate the docking angles and port positioning of the robotic arms for left-sided (2a) and right-sided (2b) RAPNx as recommended by Medtronic®.

Figure 2.

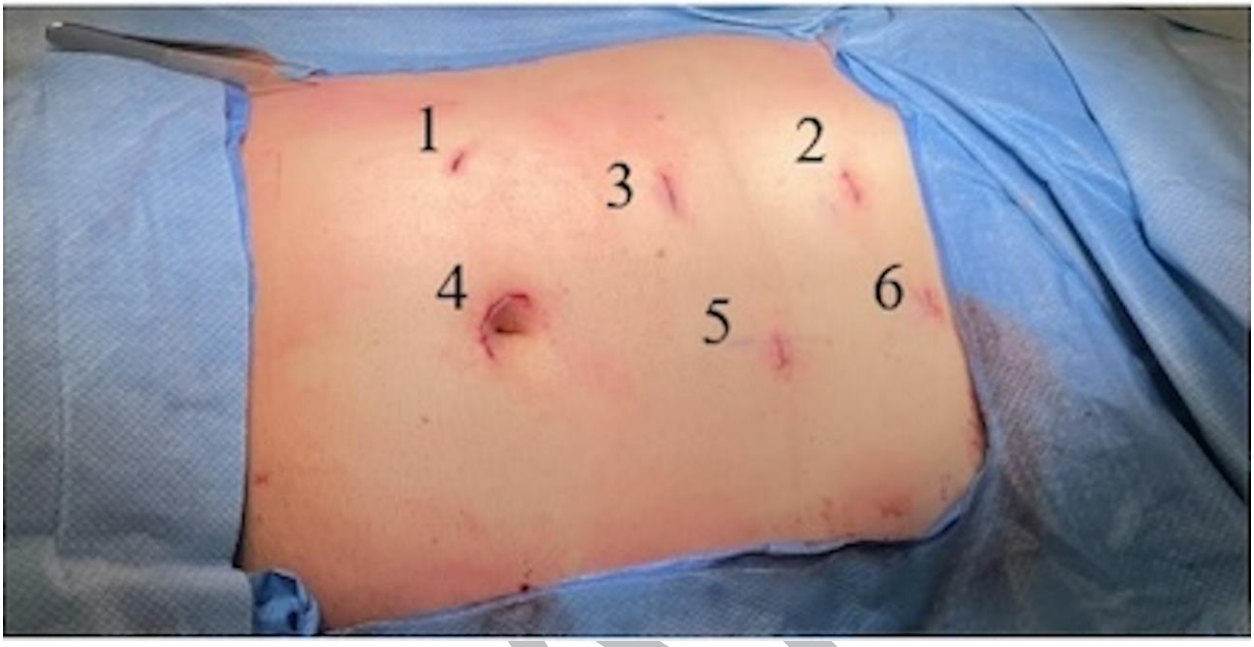


Table 1. Preoperative patient characteristics	
Median age (IQR)	58 (18)
Sex	
Male	6 (54.5%)
Female	5 (45.5%)
Median BMI (IQR)	28.3 (13.7)
ASA	
1	1 (9.09%)
2	1 (9.09%)
3	9 (81.8%)
Chronic kidney disease	1 (9.09%)
Diabetes mellitus	1 (9.09%)
Hypertension	4 (36.4%)
Tumor laterality	
Left	4 (36.4%)
Right	7 (63.6%)
Preoperative renal mass biopsy	6 (54.6%)

RENAL nephrometry score	
N/A	3 (27.3%)
4x	1 (9.09%)
5a	3 (27.3%)
6x	1 (9.09%)
6a	1 (9.09%)
7x	1 (9.09%)
8a	1 (9.09%)

ASA: American Society of Anesthesiologists; BMI: body mass index; IQR: interquartile range.

Table 2. Intraoperative outcomes	
Vessel clamping	
Arterial	11 (100.0%)
Venous	0 (0.00%)
Mean warm ischemia time (SD; min)	18.9 (7.12)
Mean robot docking time (SD; sec)	232 (106.5)
Mean total console time (SD; min)	93 (21.4)
Mean skin-to-skin or time (SD; min)	165.6 (34.1)
Conversion to radical nephrectomy	0 (0.00%)
Conversion to open	0 (0.00%)
Use of capsular stitch in renorrphy repair	2 (18.2%)
Use of hloseal	1 (9.09%)
Use of hemopatch	8 (72.7%)
Mean estimated blood loss (SD; mL)	179 (63.6)
Intraoperative blood transfusions	0 (0.00%)
Intraoperative complications	0 (0.00%)

SD: standard deviation.

Table 3. Postoperative outcomes	
Median hospitalization length (IQR; days)	2 (1)
Postoperative blood transfusions	0 (0.00%)
Postoperative angioembolization	0 (0.00%)
Postoperative urine leak	0 (0.00%)
Postoperative emergency department visit within 30 days	0 (0.00%)
Postoperative re-admission within 30 days	0 (0.00%)
Postoperative complication	1 (9.09%; wound infection)

IQR: IQR: interquartile range.

Table 4. Tumor pathology	
Tumor staging	
pT1a, pNx	10 (90.9%)
pT1b, pNx	1 (9.09%)
Furhman grading	
1	0 (0.00%)
2	8 (72.7%)
3	2 (18.2%)
N/A	1 (9.09%)
Margin status	
Negative	11 (100.0%)
Histologic variant	
Clear cell	8 (72.7%)
Clear cell papillary	1 (9.09%)
Papillary with biphasic pattern	1 (9.09%)
Chromophobe	1 (9.09%)
Histologic concordance with preoperative biopsy	
Yes	9 (81.8%)
No	1 (9.09%)
N/A	1 (9.09%)