Integrating robotic partial nephrectomy to an existing robotic surgery program

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Introduction: *As more centers develop robotic proficiency, progressing to a successful robot-assisted partial nephrectomy (RAPN) program depends on a number of factors. We describe our technique, results, and analysis of program setup for RAPN.*
Materials and methods: *Between 2005 and 2011, 92 RAPNs were performed following maturation of a robotic prostatectomy program. Operating rooms and supply rooms were outfitted for efficient robotic throughput. Tilepro and intraoperative ultrasound were used for all cases. Training and experiential learning for surgeons, anesthesia and nursing staff was a high priority. An onsite robotic technician helped troubleshoot, prepare the room and staff prior to starting surgery, and provide assistance with different robotic models.*
Results: *Average operative time decreased over time from 235 min to 199 min (p = .03). Warm ischemia time decreased from 26 minutes to 23 minutes (p = .02) despite an increased complexity of tumors and operations on multiple tumors. Median estimated blood loss was 150 mL. Average length of hospital stay was 3 days (range 1-9). Average size of lesions was 2.7 cm (range 0.7-8.6). Final pathology demonstrated 71 (77%) malignant lesions and 21 (23%) benign lesions.*
Conclusions: *The addition of a robot-assisted partial nephrectomy program to an institutional robotic program can be coordinated with several key steps. Outcomes from an operational, oncologic, and renal functional standpoint are acceptable. Despite increased complexity of tumors and treatment of multiple lesions, operative and warm ischemia times showed a decrease over time. An organizational model that involves the surgeons, anesthesia, nursing staff, and possibly a robotic technical specialist helps to overcome the learning curve.*

Key Words: partial nephrectomy, robotics, renal cancer, program development

Introduction

Renal cell carcinoma represents the most common malignancy afflicting the kidney. In the United States, it was estimated that sixty one thousand new renal cancers were diagnosed in 2011 with thirteen thousand people dying of the disease. The incidence of renal cancer is increasing at a rate of about 3% per year,[1] partially attributable to an increase in abdominal imaging and detection of asymptomatic, incidental masses. Despite the stage migration associated with earlier diagnosis of these less advanced tumors, mortality rates do not appear to be concurrently decreasing. Recent literature suggests this may be partially related to the morbidity associated with the overreliance on radical nephrectomy as opposed to nephron sparing surgery (NSS)[2].

While open partial nephrectomy is considered the surgical standard for NSS, large scale series comparing

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patients with open and laparoscopic partial nephrectomy (LPN) have demonstrated similar oncologic outcomes.[3,4] Robot-assisted laparoscopic partial nephrectomy (RAPN) has come to the forefront over the last several years as a minimally invasive option.[5-17] RAPN has been championed as a means of performing minimally invasive NSS that may be less demanding for individual surgeons to become accustomed to. Still the process of starting and maintaining a robotic nephrectomy program can be a challenge.

In centers that have a dedicated, proficient, and practiced robotic team, the development of a robotic nephrectomy program can be streamlined. Our experience performing several thousand robot-assisted laparoscopic radical prostatectomy (RALRP) cases as well as other robotic urologic procedures helped establish a framework for a RAPN program. Incorporation of RAPN allows for alternate use of existing infrastructure, expansion of indications, and cost efficiency. To our knowledge, an analysis of the initiation of a RAPN program has not been previously described. We present our RAPN experience in a high volume oncologic center with a history of robotic proficiency and successful outcomes.

Materials and methods

From March 2005 to May 2011, 92 consecutive patients underwent RAPN at the City of Hope Comprehensive Cancer Center. Patients were consented and enrolled in our institutional review board (IRB)-approved study. All patients with a renal mass suspicious for malignancy and possibly amenable to NSS were included. Preoperative evaluation included history and physical examination, routine laboratory measurements, chest x-ray, and computed tomography or magnetic resonance imaging. Renal nephrometry scores were calculated based on preoperative cross sectional imaging. All patients underwent preoperative metastatic evaluation and assessment of renal function.

RAPN program set up

Key program development tips that we have found helpful in creating and improving RAPN at our institution.

- Initially, a dedicated robotic nephrectomy team with either 1-2 surgeons can improve efficiency by reducing inconsistencies and allowing for case by case learning.
- Increasing robotic volumes not only in urology but in other surgical services more quickly cultivates operating room proficiency.
- Using another surgeon with significant laparoscopic experience and familiarity with retroperitoneal anatomy as the bedside assistant helps with the learning curve and patient safety.
- Safety is enhanced with an experienced anesthesia team that understands the physiologic changes and occasional dangerous side effects of pneumoperitoneum and laparoscopy.
- Having an on-site robotic surgical technician can help prepare the room and operative team and troubleshoot if technical malfunctions occur.
- Initial performance of radical nephrectomy robotically instead of laparoscopically may provide greater familiarity with robotic manipulation and comfort in the retroperitoneum.
- Operating rooms should be optimized with high quality, easily viewable video screens.
- Use of a dual console robot can be beneficial for learning and teaching.
- Video recording of operative cases should be reviewed for process improvement and for quality control.
- A dedicated nephrectomy cart can be stocked to reduce positioning time and prevent patient injury.
- Simplify the robotic docking process by rotating only the patient's bed and bringing the robot in straight.
- Insertion of a ureteral catheter can aid with identification and closure of the collecting system during tumor resection.
- Repeated intraoperative reference to CT scans and realtime ultrasound using Tilepro may guide dissection and reduce surgical margin rates.
- Robots not being actively used can be setup for ex-vivo skills training.

A nephrectomy positioning cart is brought into the room at the beginning equipped with padding, arm boards, tape, axillary rolls, etc. The patient is placed under general anesthesia. If entry into the collecting system is anticipated, flexible cystoscopy and ureteral catheter placement are performed while the patient is in the supine position. The ureteral catheter is secured to the indwelling foley for retrograde administration of dyed saline during reconstruction of the collecting system. The patient is then placed in a complete lateral decubitus position with the anterior superior iliac spine at the flexion of the table. We have not found a bean bag to be beneficial but do support the back with a rolled towel or large gel roll in addition to an axillary roll. The upper arm is placed on an airplane arm board that is secured to the bed and the table is flexed approximately 30 degrees. All pressure points are padded and tape is placed across the ankles, shoulders, and hips to secure the patient to the bed.

TABLE 1. **Preferred equipment**

Robotic instrumentation	**Laparoscopic instrumentation**
Monopolar curved scissors	Bowel grasper
Fenestrated bipolar forceps	Weck clips (small, large)
Needle drivers x 2	Extra long suction/irrigation
Prograsp forceps (optional)	10 mm Endocatch specimen bag
Maryland bipolar forceps (optional)	Laparoscopic locking fenestrated duckbill grasper
	Bulldogs
	Articulating ultrasound probe

Table 1 reviews our preferred equipment; the use of the "fourth robotic arm" is optional. The tradeoff of the additional robotic arm is greater surgeon independence and control with the downside being possibly increased instrument clashing and an additional incision. A Veress needle is inserted intraperitoneally and pneumoperitoneum of 15 mm Hg is obtained. A 12 mm camera port is placed lateral to the umbilicus in order to place an additional two or three 8 mm robotic ports and 1-2 assistant ports under direct vision. The bed is rotated so that the patient's back is facing the robot. The robot is then brought in straight and docked 15 degrees to a line perpendicular to the table.

Partial nephrectomy technique

The kidney is mobilized bluntly and sharply similar to a laparoscopic approach. The gonadal vein or ureter is followed up to the renal hilum. The renal hilum is then isolated without dissecting away the superior or posterior attachments of the kidney. The vein and artery are isolated separately with vessel loops prior to applying bulldog clamps. Location of the mass is confirmed with use of a laparoscopic articulating ultrasound probe and Tilepro system. Intraoperative ultrasound is used in all cases in conjunction with intraoperative analysis of preoperative imaging. We find the Tilepro to be most beneficial in mapping out tumors that are endophytic or with nonspherical shape. The perirenal fat on top of the mass is kept intact while the remaining surrounding fat is taken off of the renal parenchyma. The ultrasound probe is then used to identify and score in real time the course of normal renal parenchyma around the mass to aid in achieving negative margins.

One or two bulldog clamps are used to obtain arterial vascular occlusion, while occlusion of the renal vein is optional. We routinely temporarily increase pneumoperitoneum insufflation pressure to 20 mmHg to prevent venous backflow and aid in hemostasis of the surgical resection bed. The renal parenchyma is excised primarily with cold dissection while any obvious vessels are controlled with bipolar energy. The excised specimen is placed in an Endocatch specimen bag that is placed through the 12 mm assistant port and the specimen is placed in the pelvis so as not to interfere with the parenchymal reconstruction. Entry into the collecting system is confirmed by retrograde instillation of dyed saline through the preplaced ureteral catheter. Collecting system closure is carried out with interrupted 4-0 Vicryl suture. Hemostatic agents including Floseal and Bioglue are then applied to the resection bed. Parenchymal reconstruction is then carried out utilizing a running absorbable suture. Renorraphy is usually performed through application of a large locking clip (Weck) on the parenchymal suture by the assistant surgeon with additional tension being directed by the robotic arms. The bulldog clamps are removed and the specimen is extracted.

Results

A total of 92 RAPNs were performed over the study period. Demographics are listed in Table 2. Average length of follow up was 20 months. 19 patients (21%) had previous abdominal surgery with the majority occurring within the most recent 30 patients (11, $p = .03$). No specific patients were denied a RAPN based on previous surgery.

Average operative time was 212 minutes (range 132-403) which included robotic docking time. Warm ischemia time from bulldog clamp placement to removal was 24 minutes (range 10-55). No patients required intraoperative blood transfusion. Median estimated blood loss was 150 mL (range 10-1000). Postoperative blood transfusion was administered to 5 patients (5.4%). Median length of hospital stay was 3 days (range 1-9).

TABLE 2. **Demographics**

Gender, n (%)	
Female	36 (39.6%)
Male	55 (60.4%)
Age at surgery mean (range)	61.6 (31.1-86.3)
Body mass index median (range)	28.3 (18.9-41.4)
ASA, n (%)	
II	34 (37.0%)
III	51 (55.4%)
IV	7 (7.6%)

Two patients were converted to open for a total conversion rate of 2.2%. Both patients were converted due to concern regarding the ability to achieve a negative margin. A subcostal incision was made and the completion excision was performed. Mobilization of the kidney robotically allowed for a rapid completion of the case once open.

Estimated creatinine clearance measurements pre and postoperatively showed no significant difference. Average size of lesions was 2.7 cm (range 0.7-8.6). One patient had a positive surgical margin (1.1%). Final pathology demonstrated 71 (77%) malignant lesions and 21 (23%) benign lesions, Table 3. For renal cell carcinoma the histology was 80% clear cell, 15% papillary, and 4% chromophobe.

TABLE 3. **Tumor pathology**

Pathologic histology, n (%)	
Clear cell renal carcinoma	57 (62.0%)
Papillary renal cell carcinoma	11 (12.0%)
Chromophobe renal carcinoma	3 (3.3%)
Benign	21 (22.8%)

Median renal nephrometry score was 8 (range 4-10) reflecting moderate complexity of tumors. Five patients (5%) had multiple tumors so a nephrometry score was not calculated. Patients with multiple tumors resected had operative time and warm ischemia time similar to patients with high complexity nephrometry scores, 221 min and 28 min respectively. Operative time was significantly higher with moderate and high complexity tumors compared to low complexity (223 minutes versus 181 minutes, p = .02). Tumor size was different, 2.5 cm versus 3.1 cm versus 3.9 cm (p < .01) for low, moderate and high complexity tumors respectively.

We further examined the learning curve by splitting the series into three equal sized groups, Table 4. Operative time decreased from the first to the second and third tertiles, 235 min, 202 min, and 198 min respectively (p = .03). Both conversions to open occurred in the first 30 cases. Warm ischemia time decreased significantly from 26 min to 23 min (p = .02). Additionally, the most recent cohort had significantly higher renal nephrometry scores (p = .01) with only 22% being low complexity. Six

TABLE 4. **Clinical and operative parameters representing the learning curve**

Sequential cases	**Total**	**First 30**	**Second 30**	**Final 32**	**p value**
Age, median (range)	62 (31-86)	56 (36-86)	62 (31-80)	66 (35-83)	0.31
ASA, n (%)					
II	34 (37%)	11 (37%)	15 (50%)	8 (25%)	0.07
III-IV	58 (63%)	19 (63%)	15 (50%)	24 (75%)	
Operative time (min) median (range)	212 (132-403)	235 (164-403)	202 (132-339)	199 (139-399)	0.03
Previous abdominal surgery, n (%)					
Yes	19 (21%)	5 (17%)	3 (10%)	11 (34%)	0.03
No	73 (79%)	25 (83%)	27 (90%)	21 (66%)	
Renal nephrometry score, n (%)					
Low (4-6)	26 (28%)	11 (36%)	8 (27%)	7 (22%)	0.01
Moderate (7-9)	51 (55%)	18 (60.0%)	19 (63%)	14 (44%)	
High (10-12)	10 (11%)	1 (3%)	3 (10%)	6 (19%)	
Multiple tumors	5 (5%)	0 (0.0%)	0 (0.0%)	5 (16%)	

of the 10 high complexity lesions and all the multiple tumor operations came from this group. There was a trend towards increasing ASA over time (p = .07). Therefore despite operating on more complex tumors in patients with greater number of previous surgeries and increasing comorbidities, operative and warm ischemia times improved with the learning curve.

Discussion

Along with oncologic and functional outcomes, preservation of nephrons is a key consideration in renal surgery.[21-27] Patients presenting with renal masses often have existing renal insufficiency that should be taken into consideration when considering a surgical approach.[28] Patients with hereditary disorders such as Von Hippel Lindau disease, others at risk for bilateral or multifocal tumors, or patients with solitary kidneys also benefit from NSS. Some suspicious lesions turn out to be benign on final pathology and others may exhibit low metastatic potential. In all these instances, NSS provides the long term benefit of conserving functional renal mass. There is no present means to unequivocally diagnose or determine the biological behavior of renal tumors, thus a conservative surgical approach of NSS seems justified.

In critical analyses of LPN series, the most commonly cited drawbacks include technical difficulty, increased warm ischemia times (WIT), and increased complications. Several reports have suggested an easier acclimatization with RAPN compared to LPN with the potential for decreased WIT.[7,10,16] Another recent multi-institutional international study demonstrated comparable oncologic outcomes and preservation of renal function with fewer complications than LPN.[29] The results of this study are listed side by side with our experience in Table 5. In comparison to current RAPN literature, our series has similar demographics as well as operative parameters and postoperative outcomes. A slight increase in WIT partially reflects the learning curve but may also be attributed to non-discriminate treatment of hilar, endophytic, and multiple lesions of varying complexity. In our experience, reasons for transitioning from LPN to RAPN include increased familiarity with robotics with experience, ease of intracorporal suturing and superior vision, and economies of scale. Although this analysis reflects our initial experience and learning curve, we did not have any patients with planned partial nephrectomy that ultimately ended up with a radical nephrectomy.

The impact of robotic surgical systems continues to grow worldwide. RALRP remains the most commonly performed robotic procedure in urology. Some hospitals have designed their robotic program around RALRP with much success[30-35] and established a benchmark. As robotic case volumes increase, centers may branch out incrementally to develop additional programs such as for robotic nephrectomy and cystectomy. Sorenson et al described several key aspects of a robotic program

TABLE 5. Comparison to a contemporary series

	Yuh et al 2012 (n = 92) Single institution	**Benway et al 2010[29] (n = 183) Multi-institution**
Age (years)	61.6	59.3
Body mass index (kg/m^2)	28.3	30.3
Tumor size (cm)	2.7	2.87
Operative time (min)	212	210
Warm ischemia time (min)	24.0	23.9
Estimated blood loss (mL)	150	132
% malignant	77%	68%
Positive margin rate	1.1%	2.7%
Conversion rate	2.2%	1%
Hospital stay (days)	3	Not recorded
Renal nephrometry scores		
Low complexity (4-6)	26 (28%)	Not recorded
Moderate complexity (7-9)	51 (55%)	
High complexity (10-12)	10 (11%)	
Multiple tumors	5 (5%)	

including a committed administration, surgeon subspecialization, and innovation.[35] Program initiation as well as development depends on collaboration of surgical disciplines and support staff.

We began performing robot-assisted surgery in 2003 with RALRP. Other surgical services including gynecology oncology, general oncologic surgery, thoracic surgery, and otolaryngology then brought a much wider range of robotic operations aboard. This increased the familiarity and comfort level of operating room staff with robotic procedures. When first starting out, a dedicated robotic team allowed for improved efficiency and performing multiple procedures a day. In the initial growth phase of a nephrectomy program, designating one or two surgeons to perform renal surgery permits for the case repetition required for mastering the nuances of the learning curve and rapidly achieving proficiency. We found that after 20-30 cases, operative and warm ischemia times decreased significantly despite increased complexity of tumors addressed. Conversion to open was also less likely.

We believe that at least early on the bedside assistant should be another attending surgeon or surgeon with prior laparoscopic experience. This dual surgeon team has the operative experience to handle complex technical situations and complications that may arise during renal surgery. We prefer the experience level of another surgeon in cases of operative complexity for patient safety and when conversion to open has been needed.

Much of the robotic skill set is transferrable from RALRP with several important differences. In comparison to RALRP, the working space around the great vessels and renal hilum can lead to brisker, harder to control bleeding with RAPN. As the pelvic bony landmarks are not present, becoming disoriented in the retroperitoneum is more common. Thus keeping the level marker straight at all times and maintaining the horizontal orientation of the psoas muscle and great vessels is even more important. Care and time is required spent dissecting viscera out of the way, such as the liver and duodenum on the right and spleen and pancreas on the left. Small, deliberate movements of the robotic arms, constant assessment of where the robotic arms are, and appreciation of landmarks are paramount. Our experience with Tilepro has been extremely beneficial especially in complex cases of multiple or endophytic renal lesions.[36] As the robotic surgeon is not present at the bedside, clear communication between the entire surgical team is imperative for the operation to progress efficiently and precisely. An amplifying microphone system enhances the communication stream from console to bedside. The console surgeon actively involves all staff especially during vital parts of the operation such as during hilar clamping.

Having administered safe anesthesia for thousands of laparoscopic and robotic procedures, our anesthesia staff is adept regarding the unique physiologic changes and occasional dangerous side effects of pneumoperitoneum and laparoscopy.[18,19] Though RAPN is not associated with the steep Trendelenberg position commonly employed for urologic pelvic surgery, it is helpful to have an anesthesia team that is practiced in the physiologic expectations of laparoscopic surgery. Flank positioning presents different concerns; support of the axilla, padding of all extremities and joints, and airway management from the lateral decubitus position are all important considerations.

Our present operating rooms constructed in 2005 are optimized for laparoscopic and robotic procedures. Four high definition video screens and ceiling mounted LCDs project the console image throughout the room for the entire surgical team to see. Every room provides high definition video recording that is reviewed in each case to improve efficiency and technique. Our operating room storeroom is outfitted for all potentially necessary and spare robotic components.

The critical components to a successful robotic program depend on the interplay between a robust program infrastructure and the execution of the robotic team. Regarding our hospital infrastructure, many associated fixed costs of a robotic operating room were already in place prior to RAPN implementation. No operating rooms needed to be modified or re-outfitted. The robotic surgical systems were already present and training for staff versed in RALRP was minimal. The purchase of a Tilepro system and disposable instruments along with typical operational costs comprised the only added expenses. By increasing robotic usage, economies of scale are achieved and the cost per case decreases. Patient education via the institutional website, pamphlets, brochures, and by word of mouth from previous patients allowed kidney patient volume to grow.

As with any manmade device, the robotic computer system has the potential to malfunction. The error rate of the da Vinci robot is low but in 0.5% of cases still may occur.[20] Unfortunately even small malfunctions, such as instrument lockup, can significantly increase the time under anesthesia and rate of procedure abortion. We have found that with multiple robotic procedures proceeding simultaneously, there is a significant benefit to having an onsite robotic technician from Intuitive Surgical in order to troubleshoot, prepare the room and staff prior to starting surgery, and provide assistance with the different models we utilize. With the built-in self-testing of the robotic system as well as careful preparation by the surgical team, error rates can be kept to a minimum. The expertise of a manufacturer's representative allows them to decipher problems or prevent them from occurring in the first place. In our experience, the specialist is particularly handy in acting as a liaison between the surgeons and operating room nurses. The technician sets up one of the robots outside the operating room to aid trainees in practicing skills drills and becoming accustomed to the feel of the robotic console, unless all robots are being used. Robotic surgical simulators have improved over time but still do not replicate the feel and interplay between robotic master and slave.

All nurses have robotic training and experience and therefore every operating room member has a clear understanding of the case flow. Thus they can individually bring their collective experiences and understanding of the steps to each procedure. As such, the correct supplies are selected, the instruments are imminently available, and anticipation of the next surgical step allows for economical case completion as well as addressing complications.

The limitations of our analysis include a relatively small series with short term follow up in the context of a referral center that may not be generalizable. However we merely wish to illustrate our initial understanding and outline the aspects we have found beneficial to our progress. The surgical results we have seen are similar to other studies and large series of RAPNs are currently lacking. We report on our experience from a retrospective standpoint and provide a view as it relates to uniting a RAPN program within an existing robotic framework. RAPN remains an emerging methodology, and additional follow up is needed to determine that long term successful outcomes are maintained.

Conclusion

The addition of a robot-assisted partial nephrectomy program to an existing institutional robotic program can be easily coordinated with several key steps. Outcomes from an operational, oncologic, and renal functional standpoint are acceptable. Despite increased complexity of tumors and treatment of multiple lesions, operative and warm ischemia times showed a decrease over time. An organizational model that involves the surgeons, anesthesia, nursing staff, and possibly a robotic technical specialist helps to overcome the learning curve. □

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