Robot-Assisted Laparoscopic Urologic Surgery

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Minimally invasive surgery has grown exponentially over the last two decades. With smaller incisions, reduced blood loss, shortened hospital stay and time to convalescence, and reduced postoperative pain, laparoscopy has gained momentum as the preferred approach to many surgical procedures. This is especially true in the field of urology where minimally invasive approaches to nephrectomy, adrenalectomy, pyeloplasty, and prostatectomy have become commonplace.

Despite this exponential growth, complex laparoscopic procedures remain a daunting task. In urology this is particularly true with regard to pelvic surgery (i.e. prostatectomy), due to the small operative space, lack of depth perception secondary to 2-dimensional vision, and rigid instrumentation utilized in laparoscopy. The incorporation of robotics into surgical procedures has helped to allay several limitations of standard laparoscopy. With approximately 70% of radical prostatectomy operations performed utilizing a robot-assisted approach in 2008, it is clear that robotics have been well received in urology.[1] With its increased utilization, **robot-assisted laparoscopic** (**RAL**) surgery has now expanded to renal surgery. As they are incorporated into surgical approaches to the kidney, the hope is that the benefits of RAL pelvic surgery will directly translate to better outcomes in renal surgery.

The DaVinci Robotic Surgical System

The first reported incorporation of robotics into surgery was in 1985 when Kwoh et al. used a robot to aid in drilling and biopsy during computed tomography-guided brain surgery.[2] Surgical robots were first utilized in urology in 1989 when a robot was implemented during transurethral resection of the prostate.[3,4] Currently the only commercially available surgical robot is the da Vinci system (Intuitive Surgical, Sunnyvale, California).

Surgical robots fall into one of 3 categories: (a) active; (b) semiactive; and (c) master-slave systems.[5] In an active system the robot performs the procedure autonomously. A semiactive system incorporates both autonomous and surgeon-driven elements. Finally, a master-slave system is one in which the surgeon is in complete control of the robot from a remote station. The da Vinci robotic system is a master-slave system: the surgeon resides at a console separate from the patient, but within the same operative suite, and directly manipulates the robot to perform the surgical procedure.

The da Vinci system consists of an operator console and a patient side robotic tower that houses 3 to 4 surgical arms. These consist of a central arm that holds the camera and 2 or 3 instrument arms. The camera incorporates two separate lenses to provide a 3-dimensional visual field for the operating surgeon and also provides up to 10x magnification. In addition to the improved visualization, the instrument arms provide the surgeon with 7 degrees of freedom allowing for movements that mimic a human wrist. (Figure 1) These advantages help to filter out human tremors, provide the surgeon with a comfortable position from which he or she will operate, and provide for more facile intracorporeal suturing.

Despite the benefits of the da Vinci surgical robot, there are disadvantages. The initial cost of the system exceeds $1.5 million; and the instruments have a limited life, with 10 uses allowed at a cost an average of $180 for each use.[6] Also, robotic surgery does not provide the surgeon with haptic feedback: the surgeon must rely on visual cues, requiring a learning curve during manipulation of instruments and tissues.

Table 1. Patient Data

Mean Demographic Data (Range)	
Age	60.4 (43-74)
BMI	27.7 (19-41)
ASA Score	2.2 (1-6)
Oncologic Data	
Mean PSA	5.6 (0.1-30)
Mean Prostatic Volume	40.9 (14-130)
Preoperative Gleason Score	
Mean	6.4 (5-9)
2-6	202
7-10	120
Pathologic Staging	
T2a	54
T2b	3
T2c	210
T3a	37
T3b	15
T4	1
Operative Characteristics	
Mean Console Time (min)	180.3 (48-480)
Intra-Operative Transfusions	1
Post-Operative Transfusions	10
Mean Length of Hospitalization (days)	2.26 (1-23)
Postoperative Positive Margins (%)	
All	62/322 (19.25%)
T2	40/267 (14.98%)
T3	22/52 (42.31%)

Image 1: Endowrist articulated instruments with 7 degrees of freedom. *2005 Intuitive Surgical, Inc.* [Image courtesy of intuitivesurgical.com 2009]

Robot-Assisted Laparoscopic Radical Prostatectomy (RALRP)

Prostate cancer is the most common non-cutaneous malignancy of men in the United States. In 2009, an estimated 240,000 new cases will be diagnosed, with approximately 80,000 cases (33%) considering **radical retropubic prostatectomy** (**RRP**) as their treatment. Traditionally, RRP has been performed with an open midline incision from below the umbilicus to the pubic bone, often associated with significant hospital stay and blood loss. Recently, **robot-assisted laparoscopic radical prostatectomy** (**RALRP**) has become the preferred approach for those patients undergoing the operation. In 2008, an estimated 70% of RALRPs were performed robotically.[1] As the national and international experience has evolved, the literature on various urologic robotic experiences has rapidly grown. Clearly, surgeons are accepting and adopting the technique as first-line surgical treatment for prostate cancer.

In Rhode Island, RALRP has been performed since December 2006. Throughout this experience, over 600 radical prostatectomies have been performed robotically. The Rhode Island program is among the fastest growing robotic programs in the United States. A total of 322 of these procedures were available in our database for review at the time of this report (Table 1). Of these, the mean age was 60.4 years with a **body mass index** (**BMI**) of 27.7. The average prostate volume and PSA of our patients were 40.9 cubic centimeters and 5.6 ng/mL, respectfully. Throughout our operative experience our mean console time, as a surrogate for operative time, was 180.3 (48-480) min. Overall, 87% of patients underwent nerve-sparing techniques for preservation of potency. Only 1 patient required an intra-operative blood transfusion and a total of 10 patients necessitated a postoperative transfusion. When our data were examined more closely, however, in our last 83 patients there have been no intraoperative transfusions and only 1 (1.2%) postoperative transfusion. When hospital data were reviewed, the mean length of stay was 2.26 days of which 25.8% had <24 hr hospital stay, significantly less than the 2-4 day hospital stay previously observed with open radical prostatectomy. Our patients experienced an overall complication rate of 17.4%, with a major complication rate of 4%.

Since early 2007, the Rhode Island experience is in line with the international and national experience, with regards to safety and efficacy. There has been a significant impact on the number of prostate surgeries done in Rhode Island, with a quadrupling of the cases done at the Miriam Hospital in 2008.

Robot-Assisted Laparoscopic Nephrectomy (RALN)

The first reported RALN was by Gill et al.[7] in 2000. In this report the Zeus robotic system (a bed-mounted master-slave system that is no longer commercially available) was utilized to perform a nephrectomy on five pigs. The procedures were performed uneventfully with an average operative time of 85.2 minutes. The success of this procedure prompted the utilization of the Zeus system to perform a nephrectomy on a human. A simple nephrectomy was performed on a hydronephrotic kidney without intraoperative complications and an operative time of 200 minutes.[8]

Thereafter, surgeons expanded use of the da Vinci surgical system to renal surgery. RAL nephroureterectomy,[9] radical nephrectomy,[10] and donor nephrectomy[11] have been described. In 2005 Klinger et al.[10] reported their single institution initial results with da Vinci robotic radical nephrectomy. Of five men undergoing the procedure (median age 72) there was a single conversion to hand-assisted laparoscopic nephrectomy due to bleeding, and no perioperative morbidities or mortalities were observed. The authors concluded that RALN is a viable alternative to open and laparoscopic nephrectomy but warrants larger comparative studies prior to widespread utilization. Unfortunately, no large prospective or randomized trials exist and the available series and case reports have failed to show any significant advantage over conventional laparoscopic techniques.[12]

In the literature the use of robotics in donor nephrectomies continues to be among the largest ongoing reports of RALN. Renoult et al.[11] reported the first series of RAL donor nephrectomy performed completely with the da Vinci system in 13 patients. The authors compared this experience with 13 open donor nephrectomies performed at the same institution. The authors documented no intraoperative complications in both groups and the duration of hospitalization was significantly decreased in the RAL group. Despite this, a significantly increased operative time, warm ischemia time, and cold ischemia time were experienced with the RAL approach. These authors determined that there were no adverse effects and the grafts from both groups were found to have similar 5-day creatinine clearance.

Further prospective, randomized studies are necessary to delineate the utility of the RALN. Standard of care in Rhode Island remains laparoscopic radical nephrectomy, without robot-assistance.

Robotic-Assisted Laparoscopic Partial Nephrectomy (RALPN)

Open nephrectomy is considered the standard of care for management of both small and large renal cell carcinomas. Recently, however, laparoscopic partial nephrectomy has developed into an ideal procedure for patients with exophytic small (< 4cm) renal masses. In addition, as experience with minimally invasive surgical techniques has grown, patients with larger or multiple tumors, especially in the setting of diminished renal function and genetic predisposition, are being offered nephron, sparing surgery.[13,14]

RALPN has developed as a modality to facilitate hemostasis, tumor excision, and renal reconstruction that present significant barriers to laparoscopic partial nephrectomy. The first report of RALPN was in 2004 by Gettman et al.[15] in which 11 transperitoneal and 2 retroperitoneal RALPNs were performed without intraoperative complications. In this series there was one postoperative ileus and RCC was found in 10 cases. One positive margin was identified; however, a subsequent nephrectomy demonstrated no residual cancer on final pathology.

In 2005 Phillips et al.[16] reported their technique for RALPN and demonstrated it as a feasible, safe, and reproducible procedure in 12 patients with a mean tumor size and EBL of 1.8 cm and 240 mL, respectively. This technique, in which the robot is docked after standard laparoscopy is used to mobilize the kidney and renal hilum as well as expose the tumor capsule, was then employed in 10 patients and subsequently compared to 10 patients undergoing conventional laparoscopic partial nephrectomy at the same institution.[17] The authors found no significant differences in operative time, ischemic time, EBL, hospital stay, change in creatinine, and change in hematocrit between the two groups. All patients in both groups had negative intraoperative margins. On final pathology, however, a single patient with oncocytoma in the laparoscopic group was found to have a positive margin. They concluded that further study is needed to determine the advantages of RALPN over conventional laparoscopy and added that they no longer perform RALPN at their institution.

From these studies and the additional literature, it is clear that RALPN is a safe and feasible procedure. What remains unclear is whether or not it provides any advantages over the conventional laparoscopic approach that has been adopted at many centers. Larger randomized series will be necessary to answer these questions. Locally, we continue to employ the laparoscopic method partial nephrectomy, although a robotic protocol is being fomulated for more complex and intrinsic lesions.

Robot-Assisted Laparoscopic Pyeloplasty (RALP)

When the advantages of the da Vinci surgical robotic system are scrutinized, it is clear that the system is most beneficial in a reconstructive setting where intracorporeal suturing is extensive and precision is paramount. This advantage is evident during RALP.

The Anderson-Hynes dismembered pyeloplasty has become the gold standard for the management of UPJO with a reported success rate of 95-99%. The success rates of RALP range from 89-100% and compare favorably with the open gold standard.[18]

An initial report of the utilization of the Zeus robotic system to perform pyeloplasty in a porcine model generated interest in RALP.[19] These authors determined that the use of the robot resulted in increased anastomosis times, but the "tightness" of the repair, when compared to laparoscopic suturing, was equal. In a follow-up study the Zeus system was compared to the da Vinci system for performing various procedures in the porcine model. The da Vinci robotic system allowed the surgeon to complete the anastomosis faster and secure it with more bites.[20]

In the initial human experience the Anderson-Hynes dismembered pyeloplasty was performed in 9 patients using the da Vinci robotic system with an overall subjective and objective success rate of 100% at mean follow-up of 4.1 months.[21] Gettman et al.[22] later compared RALP to standard laparoscopic pyeloplasty: 6 patients in the RALP group were compared to similar laparoscopic patients. The patients treated with a robotic approach had a shorter operative time and suturing time. When blood loss, hospital stay, and complications were compared, however, there were no differences between the groups. This robotic series was updated 2 years later with 49 patients.[23] Mean operative time and estimated blood loss were 124 min and <50 mL, respectively. Outcomes were reviewed in 41 of these patients with a mean follow-up of 7.4 months: there was 100% success on diuretic renal scan or IVP.

In the largest RALP series to date Dr. Patel reported results on fifty patients undergoing dismembered pyeloplasty with at least 11 months of follow-up:[24] there were no complications and blood loss was minimal. The patients were followed with diuretic renal scan at 1 month, every 3 months for 1 year, every 6 months for a second year, and annually thereafter. Of the 50 patients, 48 (96%) had both objective and subjective improvement.

The RALP has been proven technically feasible and safe, with outcomes that are equivalent to those of laparoscopic pyeloplasty. The advantages of shorter hospitalizations and operative times as well as the added facility of intracorporeal suturing and enhanced visualization make the da Vinci robot exceptionally equipped for reconstructive procedures, including RALP. At the Miriam hospital, we have an active RALP program, with approximately 20 procedures performed over the last 2 years.

Conclusion

Since the advent of robotic surgery, the utilization of the da Vinci robotic system in urologic surgery has grown exponentially. The literature documents an ongoing effort to broaden its utilization and delineate its benefits in urologic practice. The technology's benefits are most evident in procedures requiring maneuverability within a confined space and meticulous suturing, making it ideal for reconstructive procedures and pelvic surgery. Long term prospective comparisons with open and laparoscopic procedures are needed to further define the role that robotics will have in the future of urology.

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