Robotic surgery in gynecologic oncology: program initiation and outcomes after the first year with comparison with laparotomy for endometrial cancer staging

Dan S. Veljovich, MD; Pamela J. Paley, MD; Charles W. Drescher, MD; Elise N. Everett, MD; Chirag Shah, MD; William A. Peters III, MD

OBJECTIVE: The objective of the study was to evaluate outcomes during the first year of a robotic surgery program in gynecologic oncology.

STUDY DESIGN: We studied the initiation of a robotic surgery program with prospective data collection, including intraoperative times, estimated blood loss (EBL), length of stay (LOS), lymph node yields, and complications. Patients were compared with historical and contemporary open staging surgery for endometrial cancer.

RESULTS: One hundred eighteen patients underwent robotic surgery (mean age 52.5 years, body mass index of 26.3 kg/m^2, hospital stay of 32.4 hours), with 8 major and 13 minor complications. Compared with open endometrial staging (n = 131), the robotic procedure (n = 25) was longer (283 vs 139 minutes, $P < .0001$), had less blood loss (66.6 vs 197.6 mL, $P < .0001$), and had shorter length of stay (40.3 vs 127 hours, $P < .0001$) with comparable node yields (17.5 vs 13.1, $P = .1109$).

CONCLUSION: Robotic surgery is feasible in gynecologic oncology and facilitated a dramatic expansion in our minimally invasive surgical practice. Despite longer operative times, EBL and LOS are reduced and lymph node yields are comparable.

Key words: endometrial carcinoma, laparoscopy, lymphadenectomy, robotic surgery

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Despite the fact that gynecologic surgeons were the first to incorporate laparoscopy into daily surgical practice, there remains less broad acceptance within the contemporary discipline regarding routine utilization of minimally invasive techniques as compared with other specialties such as general surgery. Recently, however, in an attempt to minimize morbidity and recovery time, gynecologic oncologists have increasingly utilized minimally invasive techniques to surgically stage and treat gynecologic cancers since these procedures were first described in the early 1990s.[1-3]

Childers[2] demonstrated that laparoscopic-assisted surgical staging of endometrial carcinoma was feasible, and since then this approach has been increasingly utilized by gynecologic oncologists. Following a pilot study performed by the Gynecologic Oncology Group, which showed that laparoscopic staging of endometrial cancer is feasible,[4] the Lap 2 protocol was developed to further address feasibility and complications. This study confirmed the results of the pilot study in that laparoscopic staging was shown to be feasible with acceptable complications and a superior quality of life as compared with the open approach.[5-6]

Routine laparoscopic surgical staging, however, remains underutilized, with reasons cited including a difficult learning curve, longer operative time, need for a seasoned surgical assistant, and technical issues. Urological surgeons have overcome many of the challenges posed by laparoscopic radical prostatectomy by incorporating robotic technology into surgical practice.[7] Potential benefits of robotic technology include 3-dimensional, high-definition optics; instrumentation that allows greater range of motion, precision, and scaling; and surgeon autonomy. Recent publications report utilizing robotic technology for gynecologic procedures, such as laparoscopic hysterectomy, sacral colpopexy, myomectomy, and radical hysterectomy.[8-14]

Given what we felt were limitations of traditional laparoscopic tools in performing gynecologic oncology procedures, our group sought to expand our

From the Pacific Gynecology Specialists, Inc., Swedish Medical Center (Drs Veljovich, Paley, Drescher, Everett, and Peters) and the Division of Gynecologic Oncology, Department of Obstetrics and Gynecology, University of Washington School of Medicine (Dr Shah), Seattle, WA.

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Reprints: Dan S. Veljovich, MD, Pacific Gynecology Specialists, Inc, 1101 Madison St, Suite 1500, Seattle WA 98104. veljovich@pacificgyn.com

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ability to offer minimally invasive procedures to our patient population. Prospective data were recorded with the intention of reporting our experience incorporating this technology into our practice of gynecologic oncology at a metropolitan community tertiary care center.

Materials and Methods

Robotic surgery training and credentialing

Following selective incorporation of nonrobotic laparoscopic surgical staging procedures for endometrial carcinoma in our practice since 2002, and hypothesizing that incorporation of robotic technology would allow us to offer minimally invasive surgical staging to a larger patient population with greater safety than conventional laparoscopic techniques, we sought to implement a program using robotic technology at our primary institution. Incorporation of a successful robotic radical prostatectomy program in 2005 at our institution, initiation of a gynecologic oncology training program at the University of Washington and our hospital, and an abstract presentation at the Society of Gynecologic Oncologists 37th Annual Meeting in March 2006 by Boggess et al[15] served as catalysts to begin our program.

Given that our hospital had no existing credentialing requirements for gynecologic robotic surgery, these were developed by the Swedish Surgical Committee and Department of Obstetrics and Gynecology and included case observation of 2 gynecologic robotic procedures, training in an 8-hour animal surgical laboratory, successful completion of an online 2-hour training module, 4 hours of robotic surgical time utilizing inanimate objects, and performance of 4 proctored cases, following which the surgeon's first 10 independent cases were monitored by the committee, and privileges then expanded to independent robotic surgical practice and the ability to proctor other surgeons in this technology. The first and second author observed cases at University of North Carolina Chapel Hill Women's Hospital performed by Dr John Boggess in February 2006, completed a 2 day surgical laboratory performing hysterectomy, nephrectomy, ureteral anastomosis, and lymphadenectomy on porcine subjects in March 2006, successfully passed a training module/examination following the surgical laboratory, obtained requisite training on our hospital's machine utilizing training pegs, and began with our first proctored cases in early May of the same year.

Robotic surgical technique

All cases were performed with the da Vinci surgical system (Intuitive Surgical, Sunnyvale, CA) with port placement as follows: a 5-12-mm camera port in the supraumbilical region approximately 5-10 cm above the umbilicus or right lateral supraumbilical region (5-10 cm above and 3-5 cm to the right of the midline), depending on body habitus and whether periaortic lymphadenectomy was planned; a 5-11-mm assist port in the right upper quadrant just below the costal margin (camera and assist ports, Ethicon Endo Surgery, Cincinnati, OH); and 8-mm da Vinci instrument ports placed approximately 8-10 cm lateral to or lateral and 15 degrees inferior to the camera port. In early cases, 2 da Vinci surgical instruments were utilized: monopolar curved scissors in the right lateral port and Maryland bipolar forceps in the left lateral port. Eventually we began using a third instrument lateral to the left lateral port via another 8-mm da Vinci port to allow manipulation of the uterus, adnexae, and bladder during hysterectomy with a da Vinci fenestrated grasper.

A Koh colpotomizer and RUMI uterine manipulator were utilized to aid in identification of the vaginal fornices during hysterectomy. The uterine balloon was filled with 5-mL sterile saline and a vaginal colpo pneumooccluder balloon was filled with 60-100 mL of air (all uterine manipulator devices, CooperSurgical, Pleasanton, CA). The abdomen was insufflated using standard technique with a Veress needle, and washings were obtained and bowel mobilized into the upper abdomen in steep Trendelenburg position prior to docking the robotic arms to the camera and instrument ports.

Hysterectomy was performed mimicking open abdominal technique with the primary surgeon in the da Vinci console and the assistant surgeon positioned to the right of the patient's right upper quadrant while visualizing a monitor caudad to and to the right of the patient's right knee. Vascular pedicles were taken with bipolar cautery and transected with monopolar cautery. A circumferential colpotomy was performed with monopolar scissors on the superior margin of the Koh ring, with vaginal closure performed using 0 Vicryl sutures on GS-21 needles with interrupted figure-of-eight technique using the Mega or Suture-Cut needle driver in the right instrument port and Maryland forceps in the left instrument port.

Lymphadenectomy was performed using standard anatomic landmarks for pelvic and periaortic lymph node dissection, using Maryland bipolar graspers and monopolar scissors. Periaortic lymphadenectomy was performed from the mid–common iliac vessels cephalad to approximately the level of the inferior mesenteric artery. When hysterectomy and pelvic and periaortic lymphadenectomy were all performed, the usual sequence was periaortic lymphadenectomy followed by pelvic lymphadenectomy followed by hysterectomy. Nodal bundles were removed either individually through the right upper quadrant port using large laparoscopic graspers or using an endoscopic retrieval pouch.

Following performance of 49 procedures, we began performing radical hysterectomy in late October for our 50th case, following a similar technique utilized for open radical hysterectomy with ureteral tunnel development and parametrial, uterosacral, and upper vaginal resection, all performed with combinations of monopolar and bipolar electrocautery.

Three attending gynecologic oncologists were utilized exclusively for the first 16 cases to allow adequate exposure for training and troubleshooting early on, whereas resident physician involvement was utilized variably starting with the 17th case. A fourth attending gynecologic oncologist, who joined our group in August 2006, began performing cases in mid-September (our 35th case), and by late November we began training our gynecologic oncology fellows in the technique (our 57th case).

Institutional review board

Data collection and analysis were performed prospectively for a quality assurance project at the request of the Swedish Cancer Institute Cancer Committee. Institutional review board evaluation of the quality assurance project following presentation to the Swedish Cancer Institute Cancer Committee determined that this project qualified for exempt status for publication. Per standard procedures, analysis and reporting were limited to deidentified data. Informed consent was obtained for each procedure, and frank discussion during this process was had with each patient regarding the fact that our experience using this technology was limited (or absent for the first 2 patients).

Data collection and comparison population derivation

With the intention of reviewing our first year's experience with this new technology for a quality assurance project and specifically evaluating which specific components of each surgical procedure could be improved, we began prospectively collecting data, including surgical times for robotic docking, pelvic sidewall dissection, nodal resection, uterine artery ligation, and vaginal colpotomy and closure, as well as estimated blood loss (EBL) and surgical complications occurring within 45 days of surgery. In addition, overall surgical time from incision to closure and length of stay were recorded.

For comparison of robotic, laparotomy, and laparoscopic approaches, we reviewed office billing records for Current Procedural Terminology (CPT) codes of procedures performed during the first year of our robotic experience and the year prior, including laparoscopic and open hysterectomy with surgical staging, laparoscopic and open radical hysterectomy with surgical staging, laparoscopic-assisted vaginal hysterectomy, and adnexectomy. Comparable procedures done via laparotomy or laparoscopy were evaluated to determine changes in our practice patterns following initiation of robotic surgery and differences in body mass index (BMI), operative times, nodal counts, blood loss, length of stay, and complications between surgical modalities. Data for these comparison groups were abstracted from office charts.

Statistical analysis

Data were analyzed using Stata (version 9.2, StataCorp, College Station, TX). Descriptive statistics were initially performed, followed by data analysis to determine whether there was a parametric vs nonparametric distribution. In most cases, a nonparametric distribution was observed; therefore, the Mann-Whitney 2-sample rank sum test was utilized to determine whether there was a statistically significant difference between groups (an alpha level of less than 0.05 was considered significant). The χ^2 test was used to compare differences in complication rates between groups.

Results

Robotic surgery indications, procedures, diagnosis, and complications

One hundred eighteen total robotic gynecologic procedures were performed by our practice during the first year from May 9, 2006, to May 8, 2007, with patient characteristics and complications in Tables 1 and 2. Endometrial cancer was the surgical indication in 33 patients, with 5 of these patients having only lymphadenectomy performed for staging after prior hysterectomy. Final pathologic diagnosis revealed 35 cases of uterine cancer (9 stage IA, 9 stage IB, 6 stage IC, 4 stage II, and 7 stage III). Adnexal mass, increased risk of ovarian cancer, or ovarian malignancy or low-malignant-potential (LMP) tumor accounted for 64 patients preoperatively, with 9 ovarian cancer or LMP tumors and 2 fallopian tube cancers found on final pathologic evaluation. Cervical carcinoma or carcinoma in situ was the indication for surgery in 14 patients, with 6 radical hysterectomies, 5 simple hysterectomies, and 3 staging surgeries (lymphadenectomy only) performed. Other cancers (2 melanoma, 2 anal cancers, 1 lymphoma, and 1 vaginal adenocarcinoma) were indications for 6 surgeries, and endometrial polyps and bleeding was the preoperative diagnosis in 1 patient.

Operations included 81 simple hysterectomies (of which 21 had pelvic and periaortic lymphadenectomy and 10 pelvic lymphadenectomy), 14 staging lymphadenectomies, 13 adnexectomies, 7 radical hysterectomies with lymph node dissection (1 for endometrial cancer), 2 patients converted to laparotomy (details in next paragraph), and 1 patient with oophoropexy.

Two patients were converted to laparotomy. The first had a BMI of 49 kg/m^2 and was eventually converted for endometrial cancer staging after determining she was too obese to safely continue. The second was undergoing a radical hysterectomy, and extensive distortion and obliteration of normal avascular anatomic planes were noted, likely secondary to a recent cold-knife conization procedure, and, therefore, the procedure was converted to laparotomy.

Details of surgical complications are noted in Table 2. Two vaginal cuff dehiscences required suturing the vagina in the operating room after seeing small bowel between the anterior and posterior vagina on office examinations. These patients, the 37th and 95th in our series, had BMIs of 22 and 18.7 kg/m^2, respectively, and underwent a total laparoscopic hysterectomy (TLH)/bilateral salpingo-oophorectomy (BSO) and TLH/BSO and pelvic lymph node dissection, respectively.

Two patients suffered complications of venous thromboembolism. The first was an elderly woman undergoing surgical staging with BSO and pelvic and periaortic lymphadenectomy for a deeply invasive grade 3 endometrial cancer found on a prior vaginal hysterectomy specimen. Following initiation of anticoagulation for deep vein thrombosis in the first postoperative week by her primary physician, she had an intraperitoneal bleed, prompting admission on the 15th postoperative day, and died on the 17th postoperative day of renal failure and hy-

TABLE 1
Robotic surgery: patient characteristics

Variable	All (n = 118)	With P and PALND (n = 31)	With PLND (n = 18)	With LNS (n = 3)	No nodes (n = 66)
Age (yr)	52.5	56.5	52.8	46.3	50
Range	26–88	31–88	30–85	32–54	26–76
BMI (kg/m^2)	26.3	26.8	26.4	27.5	26
Range	17.4 to 49.4	20.2 to 41.5	17.4 to 32.8	25 to 30.1	18.8 to 49.4
Surgical time (min)	213	302.5	272	118	159.4
Range	34–465	170–464	160–465	34–207	79–299
EBL (mL)	71.3	97.5	64	28	63
Range	10–500	25–500	10–200	10–50	10–500
Node counts	15.4	17.7	13.2	4.7	N/A
Range	1–32	8–32	2–25	1–11	N/A
Node, positive		4	0	2	N/A
Uterine weight (g)	104.8	103.2	104.8	N/A	105.5
Range	24–539	29–255	40–192	N/A	24–539
LOS (h)	32.4	45.7	31	24	26.9
LOS, maximum (h)	30.8	40.0	29.1	14.5	26.3
Range	3–215	17–215	21–63	3–43	3–65

LNS, lymph node sampling; *LOS*, length of stay; *LOS, maximum*, length of stay average without single greatest duration of stay; *N.B.,* No nodes cases includes 2 cases converted to laparotomy; *P and PALND*, pelvic and periaortic lymph node dissection; *PLND*, pelvic lymph node dissection.

Veljovich. Robotic surgery in gynecologic oncology. Am J Obstet Gynecol 2008.

potension. The second complication was diagnosed with a pulmonary embolism on the second postoperative day and found to be anticardiolipin positive and was uneventfully anticoagulated.

The 2 vessel injuries included avulsion of an inferior vena cava perforating vein in a nodal bundle at the lower aortocaval junction and camera trocar placement by a resident physician, which lacerated a presacral vein. Both injuries were managed with pressure and Floseal placement without postoperative complication and without transfusion. Following radical hysterectomy, 1 patient was readmitted the 7th postoperative week with a small bowel obstruction that resolved with conservative management.

The last major complication occurred during ovarian cancer staging surgery upon noting development of sudden hypoxia, thought to occur secondary to the robotic camera arm placing pressure against the endotracheal tube and advancing the tube into the right mainstem bronchus. She was admitted to the ICU postoperatively but rapidly recovered and was discharged in 90 hours. Since that case we have used a Mayo stand to protect the patient's face and endotracheal tube during surgery.

Robotic surgery times

Surgical times for all 118 cases and select components of hysterectomy were evaluated to determine whether there was a decrease in time from the mean of the first group of procedures done (first 50% of all procedures done unless the total number is odd, in which case the odd case was added to first half of group) to the mean of the second group. Table 3 shows comparisons for various procedures (rows 1-5) and components of hysterectomy (rows 6-10). Given that one surgeon (P.J.P.) served as primary surgeon for the majority of simple hysterectomies (TLH/BSO) and endometrial cancer staging hysterectomies (TLH/BSO and pelvic with or without pelvic lymph node dissection [PALND]), her cases were evaluated as a subset to determine whether statistical significance was reached for the busiest robotic surgeon.

Robotic vs open and laparoscopic endometrial cancer cases

Over the 2-year interval from May 9, 2005, to May 8, 2007, comprising the year prior to initiation of robotic surgery and our first year utilizing robotic surgery, a total of 233 open cases meeting the CPT search criteria for abdominal or radical hysterectomy with lymphadenectomy and 94 laparoscopic cases meeting the CPT search criteria for laparoscopic adnexectomy, laparoscopically assisted vaginal hysterectomy or any case with lymphadenectomy was identified as compared with 118 robotic cases done over the year following initiation of our program. Of laparoscopic cases identified, 22 cases were excluded from further analysis either because these cases were done at hospitals other than our primary institution or on review of the operative note, it was found that additional procedures (ie, colon resection, cholecystec-

TABLE 2
Robotic surgery: complications

Complication	n (%)
Major	
Vessel injury (IVC and presacral vein)	2
Venous thromboembolism (DVT and PE)	2
Vaginal cuff dehiscence	2
Readmission for small bowel obstruction	1
ICU admission (pulmonary)	1
Total major complications	8/118 (6.8%)
Minor	
Infection (cystitis, cellulitis of cuff, or port site)	5
Genitofemoral nerve injury	4
Vaginal cuff hematoma	1
Peritoneal leak	1
Lymphocyst	1
Thrombophlebitis (extremity)	1
Total minor complications	13/118 (11%)

DVT, deep vein thrombosis; *ICU*, intensive care unit; *IVC*, inferior vena cava; *PE*, pulmonary embolism.

Veljovich. Robotic surgery in gynecologic oncology. Am J Obstet Gynecol 2008.

tomy, herniorrhaphy) were performed that would make comparisons between groups invalid. This left a total of 72 laparoscopic cases (31 adnexectomy, 25 laparoscopically assisted vaginal hysterectomy [LAVH], 12 laparoscopic staging with lymphadenectomy for unstaged cancer, and 4 LAVH with lymphadenectomy) for comparison with our robotic cases.

Of open cases identified, 80 cases were excluded from further analysis because these cases were done at hospitals other than our primary institution or on review of the operative note, it was found that additional procedures (ie, colon resection, cholecystectomy, herniorrhaphy) were performed that would make comparisons between groups invalid. This left a total of 153 open cases (131 hysterectomies with lymphadenectomy and 22 radical hysterectomies with lymphadenectomy) for comparison with our robotic cases.

Given the small number of robotic radical hysterectomies performed, we decided to compare endometrial cancer staging surgeries only, and a total of 131 cases of abdominal hysterectomy with surgical staging (72 with pelvic and periaortic lymphadenectomy and 59 with pelvic nodes only) and 4 conventional laparoscopic staging with LAVH (3 with pelvic and periaortic lymphadenectomy and 1 with pelvic nodes only) were reviewed for comparison with analogous robotic cases.

Table 4 shows comparisons of multiple variables in endometrial cancer surgical staging via robotic, open, or laparoscopic approach. The 4 laparoscopic cases performed over the 2-year interval studied are also included, but given the small number of cases, comparisons are not meaningful.

Complications are compared between robotic and open endometrial cancer staging in Table 5. As opposed to the robotic group of patients for whom complications were prospectively recorded, the laparotomy group had complications identified via retrospective office chart review.

Comment

Robotic surgery has led to changes in the pattern of care for surgically treated prostate cancer, with a dramatic shift in the United States from open to robotic radical prostatectomy, and utilization of this new technology is emerging in cardiac and gynecologic surgery. Proponents of this surgical approach cite superior visualization with high-definition 3-dimensional vision, a fully immersive surgical console environment, autonomous and precise control of camera and instrument movements, and greater instrument precision as being advantages over conventional laparoscopy. These improvements over traditional minimally invasive surgery have allowed urologists in particular to move from an open to laparoscopic approach in prostate cancer surgical management.

Gynecologic surgeons have now reported series using robotic technology in the surgical treatment of benign conditions as well as endometrial and cervical carcinoma.[8-18] We viewed these early reports as encouraging and elected to initiate a robotic surgery program in gynecologic oncology at our primary institution. Analysis of our first year of cases suggests that, compared with comparable open cases performed over the year prior to and the first year of our robotic experience, robotic surgery offers the advantages of decreased blood loss and length of stay at the expense of longer operating times. In addition, our subjective impressions is that our patients had a significant reduction in narcotic use and earlier return to normal function, although, unfortunately, these parameters were not prospectively analyzed objectively. Data from a series comparing endometrial cancer patients staged via laparoscopy or laparotomy, however, demonstrated significant improvement in quality of life (using the postsurgical functional assessment of cancer therapy-general [FACT-G] metric) at weeks 1, 3, and 6 postoperatively.[6] We would anticipate similar benefits in patients undergoing robotic laparoscopic staging.

Perhaps of greatest oncologic importance is the fact that nodal yields in the 25 robotic cases performed for endometrial carcinoma were comparable with our historic and contemporary controls of 131 open patients. Also of note is that blood loss and length of stay were significantly reduced with robotic surgery as compared with open surgery. Although data from Gynecologic Oncology Group Lap-2 suggest that reduction in hospital stay is also true of the conventional laparoscopic approach,[5] this study demonstrated a 23% conversion rate to laparotomy, as opposed to the 2% rate of conversion in our series. Robotic surgery affords greater reproducibility for the primary surgeon who maintains control of camera and instrument movements than with traditional laparoscopy, and this may account for the decreased conversion rate to laparotomy.

TABLE 3
Robotic surgery times: change from first half to last half of cases (by procedure type)

Procedure	Time (first half of cases) mean, SD (min)	Time (second half of cases) Mean, SD (min)	*P* value[a]
TLH/BSO (n = 50)	172, 36.2	158.3, 46.5	.073 (NS)
TLH/BSO, excluding appendectomy, LOA, oment (n = 44)	171.5, 35.9	145.4, 30.0	.0108
TLH/BSO (P.J.P. only) excluding LOA (n = 27)	159.1, 25.8	133.2, 18.3	.0076
TLH/BSO and P with/without PALND (endometrial cancer, n = 25)	295.5, 66.0	283.5, 55.8	.7648 (NS)
TLH/BSO and P with/without PALND (endometrial cancer, P.J.P. only, n = 14)	319.1, 67.9	302, 61.2	.7494 (NS)
Robot docking (from incision to console, n = 89)	29.2, 9.3	32.6, 10.5	.2415 (NS)
Bilateral pelvic side wall dissection (n = 52)	31.0, 13.2	24.3, 15.1	.0336
Bilateral pelvic lymph node dissection (n = 31)	65.3, 24.1	64.4, 28.5	.5861 (NS)
Colpotomy (n = 51)	22.3, 12.1	19.7, 16.8	.1126 (NS)
Vaginal cuff closure (n = 52)	34.2, 13.6	25.6, 13.1	.0089

LOA, lysis of adhesions; *Oment*, omentectomy (note: component times, rows 6-10, reflect only those cases for which specific times in question recorded); *P with/without PALND*, pelvic with or without periaortic lymph node dissection; *TLH/BSO*, total laparoscopic hysterectomy/bilateral salpingo-oophorectomy.

[a] Mann-Whitney 2-sample rank sum test.

Veljovich. Robotic surgery in gynecologic oncology. Am J Obstet Gynecol 2008.

TABLE 4
Comparisons of robotic vs open vs laparoscopic (LSC) approach for endometrial cancer staging

Variable	Robotic (n = 25)	Open (n = 131)	LSC (n = 4)	*P* value vs open[a]	*P* value vs LSC[a]
Age (yr)	59.5	63	54	.0725	.5490
Range	36–85	30–92	51–67		
BMI (kg/m^2)	27.6	32.2	24.6	.016	.1715
Range	18.7 to 49.4	16.4 to 65.8	22–29		
Surgical time (min)	283	139	255	$<$.0001	.3470
Range	171–443	69–294	220–305		
Estimated blood loss (mL)	66.6	197.6	75	$<$.0001	.2597
Range	10–300	25–900	50–100		
Node counts	17.5	13.1	20.3	.1109	.9513
Range	2–32	1–42	7–39		
Uterine weight (g)	106.5	125.9	76.3	.0622	.199
Range	42–255	30–642	36–113		
Length of stay (h)	40.3	127	28.8	$<$.0001	.4227
Range	17–215	13–576	22–47		

[a] Mann-Whitney 2-sample rank sum test.

Veljovich. Robotic surgery in gynecologic oncology. Am J Obstet Gynecol 2008.

Whereas the primary endpoints of blood loss and length of stay were improved with the robotic approach, equally important is the fact that our practice was able to dramatically expand our minimally invasive surgical program utilizing this technology. In the year prior to incorporation of robotics, our group performed only 2 conventional laparoscopic endometrial cancer staging surgeries, as compared with a total of 27 laparoscopic hysterectomies with lymphadenectomy the first year of our robotic program (25 done robotically and 2 done with conventional laparoscopy). Moreover, we performed 54 simple laparoscopic hysterectomies (50 robotic and 4 conventional laparoscopic) in the year following initiation of our program, as compared with 21 LAVH cases the year prior; 16 staging surgeries with lymphadenectomy (14 robotic and 2 conventional laparoscopic) as compared with 10 with conventional laparoscopy the year prior; and 7 radical hysterectomies with lymph node dissection as compared with none the year prior. We believe that our ability to offer minimally invasive surgery to a much larger percentage of our patient population is the direct result of the feasibility of this new technology and should be possible in other busy practice settings such as ours, even with minimal prior laparoscopic experience.

TABLE 5
Comparisons of complications for robotic vs open approach for endometrial cancer staging

Complication	Robotic (%) (n = 25)	Open (%) (n = 131)	*P* value[a]
Major			
Cardiac	0	5	
Pulmonary	0	5	
Renal	0	4	
Cerebrovascular accident	0	1	
Hematology/infectious disease	1	3	
Wound dehiscence/separation	0	9	
Vaginal cuff	1	0	
Total major complications	2/25 (8%)	27/131 (20.6%)	0.1375
Minor			
Infection (wound or urinary tract)	1	7	
Nerve injury (genitofemoral)	1	4	
Lymphocele	1	0	
Total minor complications	3/25 (12%)	11/131 (8.4%)	0.5635

[a] χ^2 test.

Veljovich. Robotic surgery in gynecologic oncology. Am J Obstet Gynecol 2008.

An obvious downside of robotic surgery is that it took much longer to perform, as compared with laparotomy, with, on average, a doubling of the total surgical time. Placement of laparoscopic ports, a uterine manipulator and colpotomy ring, and robotic docking time contribute in part to the overall longer operative times, but even taking these times into account, the surgical procedure alone is longer than the comparable open case. The implications of increased operative times cannot be overstated, given the fact that in our hands currently about 2 endometrial cancer staging procedures can be performed robotically in 1 day, as compared with 3 or 4 open procedures.

We anticipate that with greater experience our robotic operative times will decrease, and this was shown for our simple hysterectomies without staging, omentectomy, appendectomy, or lysis of adhesions for all surgeons, with a more pronounced effect for the highest volume surgeon (Table 3). However, statistical evaluation of our first 25 endometrial cancer cases did not show an improvement in time between the first 13 and last 12 cases. This may be secondary to multiple factors, including the introduction of a new surgeon 4 months into our case series, introduction of resident and fellow assistants 2 and 6 months into our case series, and increasing the BMI of patients over time, all of which would be expected to increase operative times. In addition, given that we usually alternated sides of a case between 2 surgeons, the learning curve for the busiest surgeon (P.J.P.) was likely flattened, compared with a scenario in which she performed surgery on both sides on every patient.

Because the surgeon with the highest volume of endometrial cancer-staging surgery had only 14 total cases, we anticipate that at least 20 or so cases may be necessary before demonstrating significant decreases in surgical time. Also of interest is the finding that for specific components of hysterectomy (ie, pelvic sidewall dissection and vaginal cuff closure), times were significantly shorter in the second half of patients for which times were recorded. Our docking times, recorded from incision to sitting at the console, did not show a significant decrease over time, likely because of the fact that lysis of adhesions, omentectomy, and appendectomy, procedures we performed after placing ports but before docking the robot, had a significant and unpredictable impact on consecutive docking times. Other investigators[18] who have defined docking time as the time from the robot advancing to the patient to the time that all ports are connected to robotic arms have shown decreases in docking time over time.

Compared with a recent series of patients presented in abstract form by Boggess et al,[16] our mean operative times for surgical staging of endometrial cancer were longer (163 minutes vs 283 minutes, respectively). The additional 2 hours to complete our surgical staging is likely the result of our low laparoscopic volume prior to initiating a robotic program (4 cases in the 2 years studied), as compared with the Boggess group, who have benefited from a robust long-standing program at the University of North Carolina and resultant improvements in skills and efficiency. As our program develops, we expect our operative times to continue to decrease as efficiency and skill improve.

In terms of complications, vaginal cuff dehiscence was not seen in any of our comparable open cases, which is worrisome. We hypothesize that the association with robotic surgery may be due to 2 reasons: thermal injury and technique. Given that the cuff was taken with monopolar cautery uniformly, we find it imperative now to obtain at least 1 cm bites on the anterior and posterior vaginal wall to ensure viable tissue is utilized for closure. Although we did have video documentation of the 2 cases with vaginal cuff dehiscence, it was difficult to discern any clear differences in technique between these closures and other patients with video documentation. In both cases (and, in fact, all of our cases), 0 Vicryl suture on a GS-21 needle was utilized in interrupted fashion with figure-of-8 suture technique. Subjectively, however, there did not appear to be a relatively less tight vaginal apical closure upon reviewing the videos as compared with our standard open closure, and this may contribute to a cuff separation, once the early absorbable suture dissolves. Because these were our 37th and 95th cases, there was no predilection for dehiscence early in the learning curve. As our suturing skills improve, we believe the closure will be tighter, ensuring appropriate healing from anterior to posterior.

For endometrial cancer staging, there appears to be a trend toward the open approach being associated with more major complications (21% vs 8%), but this did not prove statistically significant. It is likely that the robotic complications are accurate, given the prospective documentation, and that the open complications are underestimated, given that most of these cases were done the year before we started our robotic program, and therefore, reporting is retrospective. With greater numbers of robotic cases it may be possible to prove a lower major complication rate in our hands.

Although firm conclusions cannot be drawn between our robotic radical hysterectomy series because of the small number of patients, the advantages of robotic surgery for this complex procedure were evident in that our group had not previously performed minimally invasive radical hysterectomy, and mimicking the open procedure, we had acceptable results. Therefore, we believe this procedure is feasible and should be generalizable to gynecologic oncologists who want to offer laparoscopic radical hysterectomy to their patients but are intimidated by the difficulty of a traditional laparoscopic approach to cervical carcinoma. Ureteral, bladder, parametrial, and rectovaginal space dissection are facilitated by the dexterity and range of motion of the wristed robotic instrumentation, as well as magnified high-definition optics.

A number of factors likely contributed to our success in initiating a robotic program. Perhaps most important was a dedicated robotic surgical team at our institution who had substantial experience with nearly 100 robotic radical prostatectomies prior to our first gynecologic case. The team's ability to calibrate, apply sterile draping, and facilitate docking of the robot was well honed. We found most troubleshooting issues with docking and arm positioning are not specialty specific, and the team's experience with urologic procedures contributed to a relatively smooth integration of this technology into our surgical discipline.

Also of probable importance is that we performed the first 16 cases with 2 attending physicians present, each performing approximately half of the case. This allowed rapid early exposure to port placement, docking, arm positioning, and the mechanics of using this technology. Whereas the most prolific robotic surgeon in our group participated in 79 cases in the first year, even the least active surgeon was involved in 34 cases, ensuring constant exposure to this technology. Over the course of the first year, 31 cases had obstetrician-gynecologist resident involvement, and 10 cases had gynecologic oncology fellow involvement, such that 65% of cases were done by 2 attending physicians, which also presumably steepened the learning curve. Lastly, careful patient selection likely also played a role in our success. None of the first 27 cases met the National Institutes of Health definition of obesity (BMI greater than 30 kg/m^2), and, in the first year, only 22 of the patients (19%) were obese and 4 (3.4%) morbidly obese, an incidence of obesity likely much lower than our standard surgical population.

A logical question would be why our group did not do more laparoscopic surgical staging prior to initiation of our robotic surgery program. The first factor is that the 2 senior partners in our group did not formally train in laparoscopic training during their fellowships. Although the first and second authors did have formal laparoscopic training in fellowship, we found it difficult to incorporate into a busy clinical practice in which the assistant resident or intern changed frequently. The flat learning curve for complex minimally invasive procedures utilizing conventional laparoscopy was an impediment to adopting these procedures into clinical practice. Adding a fifth partner to the group, thus allowing each of us to dedicate more time to acquiring laparoscopic skills, as well as the initiation of a gynecologic oncology fellowship program in Seattle in 2005 and our desire to train fellows in minimally invasive techniques, both acted as catalysts to beginning our robotic surgery program.

We anticipate that our percentage of patients staged laparoscopically will continue to increase as we expand this technology to women with larger BMI. The main limiting factor to expanding our utilization of robotic surgery in this patient population has been access to the technology itself, although recent acquisition of another unit by our hospital should remove strain in scheduling patients for a robotic approach.

The issue of resident and fellow training is also a potential disadvantage to robotic surgery. In the first year of our program, resident physicians had less surgical training (were doing fewer open hysterectomies as we performed more robotically), and given the decrease in surgical experience for residents in obstetrics/gynecology in the United States, this is cause for concern. At our institution we incorporated resident assistants at our 17th case, and after the first year, the residents have assisted on 31 cases, with the fellows assisting or being console surgeon on 10 cases. This exposure to minimally invasive surgery and robotic surgery is beneficial because even our interns participate in insufflation, port placement, and docking the robotic arms. We assume that as we become more comfortable with this technology, resident and fellow participation in surgery will dramatically increase. Fellow involvement as primary surgeon for at least part of the case has been at about 50% for the first 6 months of 2007.

Our goal is to develop a specific teaching module for residents and fellows and eventual incorporation on the surgical consoles for simple hysterectomies, with the nodal dissections reserved for the fellows. Our concept of having each surgeon (primary and assistant) do 1 side of each case has worked well, and we plan to extend this approach to our fellows.

Other important questions remain. Will this technology be broadly utilized for general gynecologic surgery? Is the decrease in blood loss and length of stay found in most studies the result of robotic surgery or just laparoscopic surgery? Are there quality-of-life improvements attributable to robotic surgery greater than those reported in the Gynecologic Oncology Group Lap-2 trial?[6] Can this technology be feasibly extended to staging cancers of the ovary in which no peritoneal spread is seen on preoperative imaging? Are oncologic outcomes equivalent to comparable open cases? Continued active investigation in this field should yield answers to these and other questions as the collective experience of gynecologic surgeons evolves. ■

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Discussion

John P. Lenihan Jr, MD. Hysterectomy is the second most commonly performed surgical procedure in the United States. There is a growing body of evidence and experience that clearly shows there are significant advantages to performing these procedures in a minimally invasive fashion. Multiple studies over the last 15 years have shown that patients operated on by laparoscopy have less pain, less blood loss, shorter hospital stays, faster recoveries, and overall less postoperative morbidity.[1] Unfortunately, despite these strong data, gynecologic surgeons have been slow to adopt minimally invasive surgery.

Data from the Centers for Disease Control and Prevention show that less than 10% of all hysterectomies done in the United States utilize the laparoscopic approach; and a recent survey of gynecologic oncologists revealed that although half of the oncologists surveyed were trained in laparoscopic staging of cancer, less than 8% actually staged at least half their patients with laparoscopy.[2] Reasons cited were long operative times, steep learning curves, lack of training for surgeons who had already completed their formal surgical training, and perceived inferiority of some procedures. The development of robotic assisted surgery holds the promise of being able to overcome most of the shortcomings associated with traditional laparoscopic procedures. The ability to see in 3 dimensions, to have articulating instruments that mimic the function of the human hand and wrist, and the precision offered by scaled motion all support faster learning curves and significantly enhance the ability of the surgeon to accomplish more precise and less invasive procedures.

Gynecologic oncology is clearly the fastest growing segment in the implementation of robotic surgery. Traditionally, gynecologic oncology patients are older, sicker, and heavier and potentially have more morbidity associated with open surgeries. Robotic surgeries have been demonstrated by several authors to significantly improve outcomes in these patients including the morbidly obese. In particular, minimally invasive robotic surgeries have resulted in shorter stays, faster recoveries, and fewer complications. In addition, the precision offered by robotic assistance has resulted in higher numbers of lymph nodes recovered in the robotic cancer patients when compared with standard laparoscopy and open surgeries. This has been shown to correlate with improved patient outcomes.

Consistent with previously reported data, Dr Veljovich's team demonstrated over their first 118 cases that robotic surgery times were about double their open laparotomy times. However, their patients had one-third the blood loss of open surgical patients, one-third the hospital stay, and comparable but slightly increased lymph node recoveries. They chose their initial patients wisely in that their average uterine volumes (105 g) and patient body mass indexes (27.0 kg/m^2) were near normal. Their outcomes were exceptional and certainly were comparable or better when compared with historical controls.

As gynecologic oncologists lead the evolution to robotic-assisted surgeries by making these procedures the standard in their training programs across the country, and, as computer-based surgical simulators come online for training, we will certainly see an increasing utilization of robotic surgery by oncologists and traditional gynecologists as well. Dr Veljovich and his group are pioneers in the new frontier of computer-assisted surgery. By documenting for us their initial experiences and outcomes, we all benefit from their experience.

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