MASTER CLASS

Robotics: Enabling Technology for the Gyn.

BY CHARLES E. MILLER, M.D.

The first proponents of robotics in surgery were the cardiac surgeons, but it was the urologists who truly popularized robotic surgery. Hospitals around the country have purchased the da Vinci surgical system mainly for urologists who wanted to perform robot-assisted radical prostatectomies. Interestingly enough, the robot has enabled physicians who were virtually untrained in laparoscopic surgery to feel comfortable with a laparoscopic approach.

Even though gynecologists were the first surgical specialists to perform laparoscopic surgery on a routine basis, the acceptance of minimally invasive gynecologic surgery within our specialty remains dismally low. In a recent study submitted to the National Women's Health Resource Center by the Lewin Group, only 15% of more than 600,000 hysterectomies performed per annum in the United States are accomplished via a minimally invasive technique. This is especially sobering when one considers that 80% of the cholecystectomies are performed laparoscopically.

Given the above, it is interesting to speculate on the potential impact of robotic surgery in gynecology. Initially, it appears that gynecologists who were not previously performing advanced minimally invasive surgery are able to do so with this enabling technology.

I have put together a minisymposium on robotic surgery in gynecology that will be covered in the next four issues. With my esteemed faculty, I will discuss the topics of robotic-assisted laparoscopic hysterectomy, robotic-assisted laparoscopic myomectomy, robotic-assisted laparoscopic sacrocolpopexy, and robotic-assisted node dissection.

The first author is Dr. Javier Magrina, head of the division of gynecologic oncology, director of female pelvic medicine and reconstructive surgery, and professor of obstetrics and gynecology at the Mayo Clinic, Scottsdale, Ariz.

Dr. Magrina has written extensively and lectured throughout the world on robotic surgery, from a standpoint of both benign as well as malignant disease. For the past 2 years, he has served on the board of trustees of the AAGL and remains very active in the Society of Gynecologic Oncologists and the Society of Laparoendoscopic Surgeons.

It is a pleasure to have Dr. Magrina as the author of our Master Class in Gynecologic Surgery on robotic-assisted laparoscopic hysterectomy.

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Robotic Hysterectomy

BY JAVIER MAGRINA, M.D.

Since the first published report of a robotic hysterectomy appeared in 2001, we have gained enough experience to know that next to vaginal hysterectomy, which I believe is still the preferred approach whenever possible, the robotic approach is the next-best technique that gynecologic surgeons can offer patients.

The robotic system we use today—the da Vinci surgical system—was designed to overcome the surgical limitations of conventional laparoscopy. Indeed, it has.

My colleagues and I at the Mayo Clinic, and others elsewhere, have seen similar operating times, reduced blood loss, and shorter hospitalization for both simple and radical hysterectomies as compared with the laparotomy approach. We have experienced firsthand the increased accuracy and precision that robotics promised. Suturing is easier with robotics than with laparoscopy. The advantages of robotics—from instrument articulation to the steady three-dimensional vision—have been more than expected, surpassing the advantages of conventional laparoscopy. Our operating time for robotic radical hysterectomy, in fact, is significantly shorter than that of laparoscopy.

The learning curve for performing robotic hysterectomy, moreover, seems surprisingly short. In a case-series analysis of robotic simple hysterectomies, we found it interesting that the time spent in the operating room flattened after 20-25 cases.

A prospective, randomized study comparing robotic hysterectomy with conventional laparoscopic surgery should be completed at the Mayo Clinic by the end of this year. In the meantime, robotic hysterectomy is generally offered to patients at Mayo as an alternative whenever a laparoscopic hysterectomy is being considered.

Patients are beginning to ask for it, and indeed, there are instances when we strongly prefer the robotic approach regardless of patient demand—for example, when patients have a history of adhesions, advanced endometriosis, gynecologic cancer, or genitourinary fistula, or when we have to perform pelvic floor repair procedures or other additional procedures that require extensive suturing. Obesity is an excellent application for robotic technology, which is something we have learned as our operating time has not been influenced by a patient's body mass index.

Evolution of Robotics

We started performing hysterectomies with the Zeus MicroWrist surgical system in 2003. The system, which was approved by the Food and Drug Administration in 2002 for general and laparoscopic surgery, enabled the surgeon to operate three robotic arms while sitting a distance away from the operating table.

This Zeus system was an advance over the Aesop robotic device, a voice-activated robotic arm designed to operate the laparoscope. Released in 1994, Aesop was the first robotic system approved to assist in laparoscopic procedures. With Aesop, the surgeon would direct the robotic movement of the laparoscope through voice commands while working manually with regular instruments. Video quality thus improved, and the need for an assistant was obviated when only two instruments were needed.

With the development of the Zeus system, surgeons gained two more robotic arms (in addition to the laparoscope-operating arm) as well as some of the other advantages afforded by robotics, such as articulating tips and a downscaling of movement.

The da Vinci surgical system that we use currently is an improvement over Zeus. It was originally approved for procedures in the abdominal and pelvic cavity, but in 2005 it received special approval for the performance of robotic hysterectomy. At this point, because of various changes in the industry's structure, it is the only robotic system manufactured for laparoscopic procedures.

In an evolution that reflects likely future changes as well, a second generation of the da Vinci system, released in 2006, has longer instruments, lighter arms, and increased flexion-extension and lateral excursion, among other improvements.

Instrumentation and Process

We now refer to the approach as "robotic" hysterectomy rather than "robotic-assisted" laparoscopic hysterectomy because—although a surgical assistant is still needed for several key functions, such as suction and irrigation—the procedure is, with these latest advancements, largely robotic in nature.

With most hysterectomies, as with most pelvic operations, four trocar sites are used: three for the robotic arms (one of which is for the laparoscope) and one for the assistant, who will manually perform suction, irrigation, vessel sealing, tissue retraction, and specimen retrieval. When we have a patient with cancer, obesity, a large uterus, advanced endometriosis, or adhesions, we add a fourth robotic arm. This additional arm allows for the added retraction of tissues.

We use the open Hasson technique to place a 12-mm robotic trocar (the first of the three main trocars) in the umbilical area for the laparoscope. Two 8-mm robotic trocars are then placed bilaterally, 10 cm to the right and left of the umbilicus. This placement provides an operative field that extends, in most patients, from the lower pelvis up to the inferior mesenteric artery.

For the assistant, a 10-mm trocar is placed 3 cm cranial and right between the umbilicus and the left robotic trocar. Through this port, the assistant performs the functions that are not yet available robotically: vessel sealing, suction, irrigation, tissue retraction, specimen retrieval, and the introduction and retrieval of sutures and needles. When a fourth robotic arm is used, that trocar is placed 10 cm lateral and 10 cm caudal to the right robotic trocar.

The robotic tower with three arms is situated between the patient's legs. We have noticed that if the column is parked very close to the patient's perineum, there is inadequate space for the scrub nurse to mobilize and manipulate a vaginal probe, maintain the pneumoperitoneum during vaginal incision, and retrieve specimens vaginally. Ideally, the robotic column should rest at about the level of the patient's feet and not any closer.

The middle robotic arm is attached to the umbilical trocar where the laparoscope has been inserted. A monopolar spatula, or scissors, is inserted through the right lateral trocar, and a plasma-kinetic dissecting forceps is inserted through the left lateral trocar. When needed for suturing, a needle-holder replaces the spatula. When a fourth robotic arm is needed, a robotic instrument called a Prograsp is used.

The surgeon sits, unscrubbed, on a console that in our operating suite is about 12 feet away from the patient. Here the surgeon can manipulate the robotic arms that maneuver the instruments and the laparoscopic camera, as well as communicate verbally with the assistant. When the surgeon is playing the role of assistant and the trainee is at the console, the surgeon can direct the trainee by means of telestration to pinpoint anatomical structures and planes of dissection, or to indicate areas of potential visceral damage by drawing circles, arrows, or dots.

When the ovaries are to be removed, which in our practice is more common than not, our first step with robotic simple hysterectomy is to incise the pelvic peritoneum at the level of the pelvic brim to identify the ureters and the points at which they cross the ovarian vessels. We then coagulate and divide the infundibulopelvic ligament that contains the ovarian vessels.

The ureters are then traced and followed to the point where they cross the uterine arteries. Because we cannot palpate the tissues in robotic surgery and therefore need to see, we dissect the ureters anytime they appear close to the cervix or if there is parametrial pathology. Doing so prevents injury.

After this, the bladder must be dissected from the cervix and upper vagina, and at least 2 cm caudal to the anteri-

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or vaginal fornix. A vaginal probe that is inserted into the vagina by the scrub nurse is used to identify where the vagina joins the cervix and to define the level of incision on the vagina.

A vessel-sealing device is used to coagulate and transect the uterine arteries and the cardinal ligaments. At that point—and not any sooner—the vagina is transected immediately distal to the cervix and the uterus is detached and removed, along with the ovaries in most cases, through the vaginal opening. (When the ovaries are not removed, they are left attached to the ipsilateral round ligament.) The scrub nurse holds the labia majora to the midline over the surgical instrument used to remove the uterus, and that is enough to maintain the pneumoperitoneum.

Inflation of a sterile occluding balloon with 60 mL of saline is used to maintain the pneumoperitoneum after removal of the specimen vaginally.

The right monopolar spatula is then removed and replaced with a needle-holder, and the vaginal cuff is closed with a 15-cm precut 0 continuous polyglyconate absorbable suture starting at the right angle and going toward the midline. A similar 15-cm suture is applied from the left to the midline until it meets the other suture. The uterosacral ligaments are incorporated at each vaginal angle and at the midline in order to support the vagina. We use a LapraTy suture clip at each end of the sutures to eliminate the need for intracorporeal knot tying.

Using these small precut sutures is most helpful. A suture that is 30 cm long simply takes too long to pull through the tissues. In general, the use of smaller, shorter sutures is essential in robotic surgery.

For robotic hysterectomies as well as any other robotic gynecologic surgery, I also advise using slow, deliberate, precise movements. Such pacing alleviates the risk of bleeding, which dramatically slows the procedure down when it occurs.

At the end of the procedure, the robotic arms are disengaged from the trocars, the robotic column is moved away, and the fascia at the umbilical site is closed. The other trocar sites require closure of only the skin. We always perform a cystoscopy after injection of intravenous indigo carmine to ensure that there are bilateral ureteral jets and no injury to the bladder.

When we plan to send the patient home on the day of the robotic hysterectomy—something we started doing when we observed how well patients were faring with this approach—we modify the anesthesia regimen somewhat.

We give each patient dexamethasone preoperatively, apply an antinausea patch behind her ear, and administer two additional medications to prevent nausea: Zofran (ondansetron) and aprepitant. Then, at the end of the hysterectomy, we inject both the right and the left pelvic plexus (sympathetic and parasympathetic) with a cocktail of morphine, vasopressin, and Marcaine (bupivacaine). We also infiltrate the trocar sites with Marcaine, and before the patient is awakened from anesthesia, we administer intravenous ketorolac. When she is awake, the patient will then have minimal discomfort.

Additionally, normal saline (200 mL) is left in the bladder at the end of the cystoscopy so that the patient will have the urge to empty her bladder in the next hour rather than the need to wait up to 5 hours to empty her bladder before being able to go home.

In our preoperative discussions with patients, we do inform them that the incisions are placed a little higher than with conventional laparoscopy. Only once has one of our patients expressed cosmetic concern and opted for a laparoscopic approach with suprapubic trocar placement.

Hysterectomy has been a natural beginning application for robotic technology in gynecologic surgery. Experience with the approach has applications, in turn, for other gynecologic procedures because the same instrumentation and usually the same port placement are used.

Patient Outcomes

In a series of 91 consecutive patients who underwent robotic simple hysterectomy at Mayo (with or without salpingo-oophorectomy or concomitant appendectomy) between March 2004 and December 2005, we had no conversions to conventional laparoscopy or laparotomy, no bladder or ureteral injuries, and few intraoperative and postoperative complications (Am. J. Obstet. Gynecol. 2007;197:113.e1-4).

Our one intraoperative complication was an enterotomy that was repaired robotically in a patient with extensive pelvic adhesions. (We have learned that complications can be repaired robotically without having to convert to laparotomy.)

Postoperatively, one patient with cardiomyopathy required admission to intensive care for 24 hours for exacerbation of heart failure, and another patient required admission for vaginal cuff abscess. Three patients were readmitted for ileus, pneumonia, and colitis. The mean estimated blood loss was 79 mL, and the mean hospital stay was 1.3 days. (Indications in the patients, whose mean age was 50 years, included menometrorrhagia in 43% and ovarian neoplasm in 20%.)

In the evaluation of robotic surgery and analysis of the experience, it is important to break down the total process into several components: docking time (the time required to attach the robotic arms to the trocars), console time (the surgeon's time dedicated exclusively to performing the hysterectomy), and total operating time (from incision to closure).

For surgeons who haven't used the robotic system, a common misperception is that it takes a long time to set up for each procedure. In our series, however, the mean docking time was only 2.9 minutes.

The mean console time was 79 minutes, and the total mean operating time was 122 minutes, which was 14 minutes shorter than conventional laparoscopy. A mean of 43 minutes was required for setup and close, which included trocar placement, exploration, and the removal of trocars, closure, and cystoscopy. (The time for setup and close has not been reported before in laparoscopic surgery.)

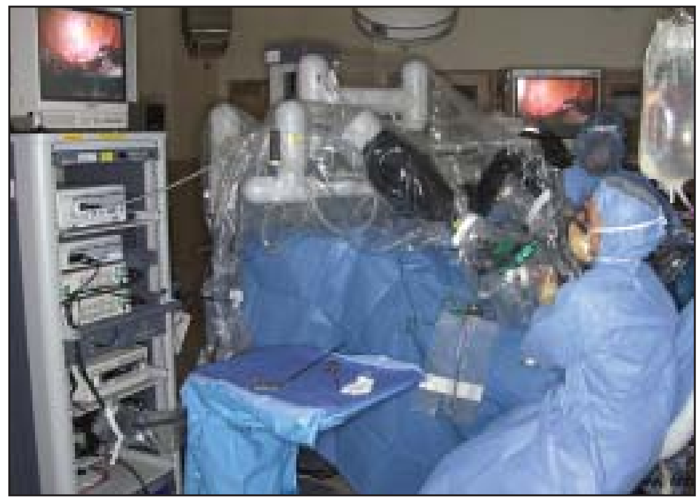
Our surgical time was minimized by having a dedicated robotic team and by using certain surgical strategies, such as the use of only three instruments (monopolar spatula, bipolar grasper, and needle-holder) for the entire procedure—a practice that also reduces cost—and the use of precut, short sutures and suture clips. The optimal robotic team can comprise two surgeons or one surgeon and one assistant, as well as at least two nurses who are well versed in the robotic instrumentation and system. The assistant also plays a major role in fixing any malfunctions of the robotic instruments or arms, and in switching robotic instruments.

Console time clearly decreased over time as we performed more simple hysterectomies. It was not significantly affected by the performance of an appendectomy, but it was affected by uterine weight and the lysis of adhesions. In our practice, we prefer a vaginal approach for the larger uterus that requires more morcellation. In general, our threshold for the robotic approach is a uterus of 12-14 weeks' gestational size.

All of these findings—from reduced operating times to shorter hospitalizations and fewer complications—have applied to our experience with robotic radical hysterectomy as well. In one analysis of 16 patients undergoing robotic radical hysterectomy, we found that total operating time was 66 minutes shorter than it had been for laparoscopic radical hysterectomy.

An increased body mass index did not prolong operating times in any of our patient groups. In fact, we have noticed that for patients who are obese, surgical time is longer with laparoscopy than with robotics. This reflects one of the advantages of the robotic approach: It bypasses the fulcrum effect, which is inherent to conventional laparoscopy and which is especially challenging in patients with a thick abdominal wall. Surgeons using the articulated instrumentation of a robotic system will use the same manual effort regardless of how thick the abdominal wall is.

Four robotic trocars are placed in preparation for pelvic surgery with the da Vinci robotic system.



The da Vinci robotic system is shown in operation, with the assistant sitting to the left of the patient.

PHOTOS COURTESY DR. JAVIER MAGRINA

The Zeus robotic system consists of two working arms and another to hold the laparoscope.

The lack of tactile feedback is viewed by some as a limitation of robotics, but after a short time of practice, it is easily compensated for by the depth of perception that three-dimensional vision affords.

In addition, the articulation of the instruments facilitates dissection of the tissues and suturing, such as closure of the vaginal cuff in hysterectomies. And as with other gynecologic surgeries, the downscaling of the surgeon's movements in a 3:1 or 5:1 ratio leads to increased accuracy and precision. (In such downscaling, when the surgeon's hand moves 3 cm or 5 cm, the tip of the instrument moves only 1 cm.)

We still believe that when the hysterectomy can be performed vaginally, the vaginal approach is preferable to robotics or to laparoscopy. This is because any study that has compared vaginal hysterectomy with another approach has demonstrated a faster operating time with the vaginal procedure, as well as lower cost.

When a patient is not a candidate for a vaginal hysterectomy, or when the gynecologist is not comfortable with the approach, however, then the robotic approach is indeed preferable to conventional laparoscopy. ■

DR. MAGRINA *reports no financial disclosures.*