Chapter 17
Robotic Surgery

Jed Delmore

Kevin E. Miller

DEFINITIONS

Learning curve—Defined as the length of time or number of cases to reach a predictable operating time, the fewest complications, or lowest blood loss.

Patient-side cart—A mobile cart composed of a camera arm and three operating arms that attach to the laparoscopic ports.

Robot—A machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.

Surgeon console—A mobile cart composed of a stereoscopic viewer, master controllers, and a series of foot pedals.

Uterine manipulator—One of several instruments inserted in the uterus with an attached colpotomy ring to facilitate movement of the uterus and visualization of the vaginal fornix.

Vision cart—A mobile cart containing the vision system for image processing, light source, carbon dioxide insufflator and energy sources, and usually a video monitor.

INTRODUCTION

History

The technologic advances in minimally invasive surgery, specifically gynecologic surgery, over the past 50 years are staggering. Using monocular laparoscopes with continuous carbon dioxide insufflation of the peritoneal cavity, most gynecologists in the United States in the early 1970s were performing diagnostic laparoscopy and tubal sterilizations. Within a short period of time, video laparoscopy allowed a rapid expansion in procedures performed by the minimally invasive approach. Salpingectomy, oophorectomy, myomectomy, resection and ablation of endometriosis, hysterectomy, and a long list of other procedures, are now commonly performed. Until recently, most technologic advances in laparoscopy have involved video equipment, instrumentation, and newer energy sources. A combination of astounding technologic advances has resulted in the introduction of robotic or robotically assisted surgery in gynecology, and astute, aggressive marketing to physicians and the public has resulted in the rapid assimilation of robotic surgery into today's surgical practices. However, controlling the application of robotic technology and teaching the procedures seem to lag behind the marketing.

According to the Oxford Dictionary, “robot” is derived from the Czech word *robota* meaning “forced labor.” The term was introduced in Karel Čapek's play *“Rossum's Universal Robots”* in 1920. A robot is defined as a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer. The history of robotic surgery is best described as a convergence of research performed in multiple locations in the 1980s. Expanding on the technique of stereotactic brain biopsies, Kwoh and colleagues modified an industrial robot, the Unimation PUMA (Programmable Universal Machine for Assembly) 200, for the biopsy of brain tumors in 1988. In 1991, Davies et al., at the Imperial College of Science, Technology, and Medicine in London reported the use of a modified PUMA 560 robot, which later became PROBOT, for transurethral resection of prostatic tumors. During the 1980s and early 1990s, researchers at the National Aeronautics and Space Administration Ames Research Center were working on virtual environments while researchers at the Stanford Research Institute were working on robotics and a telemanipulator system for hand surgery. As described in a review by Satava, the Department of Defense and the Defense Advanced Research Projects Agency funded research directed toward the concept of telepresence surgery for combat casualty care. This culminated in the demonstration of a telepresence vascular anastomosis in the swine model in 1996 by Bowersox and telesurgical laparoscopic cholecystectomy in 1998 by Himpens. In 1993, Yulun Wang, PhD, formed Computer Motion, which developed a robotic camera holder for laparoscopy called Automated Endoscopic System for Optimal Positioning (AESOP) and ultimately created an integrated robotic system that attached to the operating table called ZEUS. In 1995, Frederic Moll, MD, acquired the license for the telepresence surgical system and created Intuitive Surgical. In 2003, Computer Motion and Intuitive Surgical merged into a single entity, Intuitive Surgical. Presently, da Vinci is the only robotic surgical system approved by the U.S. Food and Drug Administration (FDA) (Intuitive Surgical, Sunnyvale, CA). As a result, any reference to robotic surgery or robotic platform in the remainder of this chapter pertains to the Intuitive, da Vinci system. This is not meant to be an endorsement of this or any other product; it simply reflects the fact that there are no other commercially available robotic platforms at present.

Advantages and Disadvantages

The November 2009 American Congress of Obstetricians and Gynecologists Committee Opinion concerning types of hysterectomy concluded that vaginal hysterectomy is the approach of choice whenever feasible, on the basis of its well-documented advantages and lower complication rates. Laparoscopic hysterectomy is an alternative to abdominal hysterectomy for those patients in whom vaginal hysterectomy is not indicated or feasible. “The experience with robot-assisted hysterectomy is limited at this time; more data are necessary to determine its role in the performance of hysterectomy.” The advantages of robotic surgery include those experienced by the patient, the hospital, and by the surgeon. The advantages to the patient include smaller incisions compared to laparotomy, shorter hospital stay, less blood loss, and a more rapid return to normal activity. Laparoscopic surgery provides the same benefits; but because of technical considerations noted below, the range of surgical procedures is greater with robotic surgery. The advantages to a surgeon include enhanced visibility with a threedimensional (3D) view, enhanced image magnification, and stable camera platform devoid of first-assistant fatigue that can result in an unstable field of view with camera motion. The instruments utilized by the surgeon are wristed to allow a full range of motion and angles similar to an open procedure. In distinction to conventional laparoscopy, which relies on a fulcrum effect and requires movement of the handle of the instrument in the opposite direction to the desired movement of the tip, robotic surgery allows hand and instrument movement in the same direction. Surgeon hand tremor is minimized, and the ratio of hand motion to robotic instrument motion can be adjusted. Sarlos reported that fatigue and back discomfort may be reduced by a more ergonomically correct position at the surgeon console. This benefit may be the greatest during longer cases. Robotic suturing may be considerably easier for most surgeons compared to laparoscopic suturing in studies reported by Andenberg and Chandra. For instructing resident physicians and fellows-in-training, the video monitor on the vision cart allows the educator to draw on the monitor that can be seen by the trainee at the console. Sonographic or computed tomographic images from preoperative studies can be projected onto the surgeon console screen for viewing during surgery. The newest da Vinci Si model allows surgeons at two separate consoles to operate simultaneously on the same patient, or it allows a mentor to intervene during a trainee's procedure. The potential advantage to the hospital or institution is a shorter patient hospital stay for procedures that historically resulted in a longer stay if performed by laparotomy. Potential disadvantages to the patient include a longer operative time and facial edema from protracted Trendelenburg position.

The major disadvantage to all parties is the cost of the robot, associated instruments, drapes, and maintenance contracts. The cost of a da Vinci robotic system varies between $1,000,000 and $2,300,000. Wristed robotic instruments, which have a limit of 10 uses, cost approximately $1,300.

For point of reference, the 2011 purchase price paid by one of our community hospitals for typical laparoscopic instruments utilizing different energy sources ranges from $350 to $450. Annual maintenance costs for the robotic system are estimated at $150,000 (Intuitive Surgical, Second Quarter Investor Presentation, http://phx.corporate-ir.net/phoenix. zhtml?c=122359&p=irol-IRHome).

Because of the size of the entire robotic system, larger operating rooms (ORs) are required for optimal efficiency and may add expense to the institution. Size and position of the robotic arms when docked may cause difficulty for the bedside assistant when passing sutures, retracting tissues, or manipulating the uterus with a vaginal manipulator.

From the surgeon's standpoint, the major disadvantage is the lack of haptic or tactile sense with the instruments. Those surgeons accustomed to blunt dissection of tissues will be required to enhance their sharp dissection skills and rely on anatomic landmarks. Those in residency training may suffer from diminished experience with traditional open procedures and operative technologies as more and more gynecologic surgical procedures are done using minimally invasive and robotic techniques.

ROBOTIC TRAINING

In 2007, Javier Magrina explained that robotic surgery "… is nothing more than an enhancement along the continuum of laparoscopic technologic advances and represents only the beginning of numerous more forthcoming advances."

Obstacles and Challenges to Teaching and Learning

Currently, there is no standardized training model or validated method to teach robotic surgery. Two notable obstacles to teaching the application of this new technology result from the unique features of robotics. Until recently, a single surgeon controlled the robotic operation without the use of a second set of independent controls for the assistant or trainee. The teacher/instructor had no ability for immediate hands-on correction as he or she would have had with traditional teaching. Thus, potential patient safety issues become a concern with implementation of robotics. The situation is likened to a student pilot on final approach without the flight instructor being able to take control of the airplane's pitch and power controls to avoid a potentially dangerous landing. The robotics instructor must correct the trainee with prompt, understandable, and verbal commands. However, dual consoles are now available, although they are expensive and not widely available. These dual consoles allow cosurgeons to work on the same patient with three moving instruments controlled by the cosurgeons in contrast to two moving instruments with a single console. Additionally, a mentor and a trainee can operate on the same patient simultaneously. The single-surgeon console in use at most facilities is a "resident-unfriendly" platform. The resident initially functions as a table-side assistant or observer, which is quite different from the usual hands-on learning experience. Hanly suggested that wider availability of mentoring consoles will likely improve resident and nonresident learning experiences and enhance patient safety. The telestration feature enables the teacher/mentor to point, draw, or illustrate directly on the video touch screen monitor as the surgeon sees this on the surgeon console screen in real time.

Another obstacle to learning robotic surgery is the lack of tactile sensation and feedback to the surgeon. Palpation of the tissues is not translated to the surgeon in the same way as one "feels" the tissues with open procedures or conventional laparoscopy. This lack of tactile sensation or haptics presents an initial challenge to learning until one is conditioned to develop a "sensation of feel" on the basis of the visual cues as proposed by Hagen and colleagues. This may be likened to an experienced pilot transitioning to flying a remote-controlled drone aircraft from a virtual cockpit far from the area of flight. Despite these obstacles, Dharia and Falcone, Stefanidis et al., and Suh et al. suggest that the robotic features of instrument motion comparable to open procedures, tremor reduction, 3D high-definition image, wristed instrument articulation, and downscaling movements have made more difficult advanced laparoscopic surgical cases with steep learning curves easier to learn and apply to patient care.

Training Methods

Initially, most robotic training regimens were developed and sponsored by Intuitive Surgical, Inc., the maker of da Vinci Surgical System. The manufacturer has been active in developing training methods and recommendations to introduce the techniques of robotic surgery to potential customers. However, with increased experience of surgeons and institutions, locally developed training protocols have placed less emphasis on the manufacturer to provide training. Initial training protocols incorporated a combination of "on-site" (hospital) training, "off-site" (laboratory) hands-on courses, as well as Internetbased modules and surgical videos. All OR team members require basic training on mechanical and technical aspects of robotic system functions (*system training*). This specifically includes learning the components of the system, how to dock, set up, and insert instruments, implement safety features, and troubleshoot malfunctions. The second aspect of training deals with acquiring the technical skills to perform surgery (*procedure training*). Training modules and videos may be accessed at http://www.davincisurgerycommunity.com.

Since there is only one commercially available robotic surgical system available in the United States today, the technical system training is still largely provided by the manufacturer. This system training can be completed with the Internet-based Intuitive Surgical curriculum including system overview, setup/docking, surgeon console functions, and safety features. The setup module instructs on port placement, camera arm positioning, instrument arm positioning, docking, endoscope insertion and removal, and instrument insertion and removal. The surgeon console module instructs on system setup and vision, ergonomic, and instrument control. The safety features module teaches how to troubleshoot fault messages, emergency switch location and use, energy source control, and procedure conversion to open or standard laparoscopy.

Procedure training is surgeon and procedure specific and directed at acquiring the needed technical skills. For the gynecologist/pelvic surgeon, a sample of the procedures performed robotically include hysterectomy, adnexal surgery, lymphadenectomy, radical hysterectomy, myomectomy, sacrocolpopexy, Burch retropubic urethropexy, endometriosis resection, and ureteral and fistula repairs. Commercially produced and Web-based surgical videos provided by surgeons are available. Inanimate simulator training, live animal models (pig lab), and case observation have been required of surgeons learning robotic techniques before being proctored by an experienced surgeon. After certification of completion of both system and procedure training, experienced gynecologic surgeons desiring to obtain robotic surgical privileges are commonly proctored at their home institution with a minimum of two to five cases before independent-use privileging is granted. Because of the high expense of animal laboratory courses ($3,000 per one to five trainees), these may not be feasible for some residency/fellowship training programs. Hoekstra and Geller have reported on nonstandardized methods developed to achieve didactic

and procedural training within their institution. Completion of a procedure training program described by Geller and associates at the University of North Carolina is required before residents or fellows performing robotic surgery. This “System Skills Practicum” includes developing proficiency in four surgical skills: (a) “manipulation drill” that requires transfer of rubber rings from tower to tower to learn wristed instrument movements and camera manipulation (clutching), (b) “dissection drill” that requires dissection of a vessel encased in gelatin using scissors and grasping instruments, (c and d) “suturing drills.” The “suturing drills” are timed and involve reapproximating linear and jagged lacerations on an inanimate model to teach needle-driver use and intracorporeal knot tying with camera and instrument clutching. These suturing drills are the most difficult to master. Surgical training programs such as residency and fellowship also typically require involvement in a minimum number of case observations in addition to working as first assistant with progressive hands-on experience.

The simulation training module connecting to the da Vinci Si model functions the same as a flight simulator or video game box. The surgeon works directly at the console on a series of exercises to learn and maintain proficiency skills in manipulation of the robotic controls. The simulation unit scores and records each exercise to allow quantification of progress. Manipulation skills of the wristed instruments, camera control, clutching, dissection, energy control, and needle driving are performed in various combinations. Surgical facilities responsible for credentialing may be able to utilize this module to assess surgeon skill retention and possibly to maintain privileges.

Does Previous Experience with Operative Laparoscopy Matter?

Several studies have evaluated experienced surgeons and inexperienced/novice surgeons with regard to skill development when learning simple and complex robotic techniques. Stefanidis and Suh found that previous experience as an assistant surgeon on robotic surgical cases shortens the learning curve, and all trainees have lessened physical demands and decreased workload with improved accuracy and precision in comparison to standard laparoscopic techniques. They also reported that surgical novices seem to learn difficult tasks such as robotic suturing more easily than experienced surgeons. Interestingly, other high-intensity hand-eye coordination activities, such as prior high-volume video game experience, were found to have a negative impact on learning robotic suturing in a study by Harper. Overall, it appears that lack of previous laparoscopic experience does not seem to be a major obstacle in learning the technical aspects of the robotic platform.

Experience with Various Energy Sources

As with standard operative laparoscopy, the surgeon performing robotic surgery should be familiar with the various energy sources, as the power settings and depth of thermal spread may be new or different from what they are accustomed to with standard laparotomy, vaginal, or laparoscopic procedures. Energy sources used with the da Vinci system include bipolar cautery, monopolar cautery (scissors), PlasmaKinetic (PK), and harmonic energy sources. If bedside assistants will be operating conventional laparoscopic energy sources, adequate education and experience are required.

What Is the Learning Curve for Robotic Surgery?

Operating time may represent an indirect measure of the learning curve for a specific surgical procedure. An efficient OR team should lead to decreased operating times. Because of the significant technical training robotic surgery requires of the entire surgical team, safety and efficiency in robotic surgery require a well-trained, experienced team, which is used to working together. The importance of the same team working together frequently with the same surgical procedures cannot be overemphasized. Several components contributing to operating times include OR personnel, surgeon, and patient factors. First, efficiency is dependent upon the OR personnel for room turnover, equipment processing and setup, and assisting the surgeon in positioning and draping the patient. Second, surgeon factors depend on his/her learning curve or experience performing the particular operation. As with any other surgical method, operating times decrease and technical proficiency increases as the frequency and volume of cases increase to a certain number. Third, patient-dependent factors that increase the difficulty of the surgery, such as morbid obesity, previous surgeries, and presence of extensive adhesions, are to be considered. The patient factors should be considered especially when selecting initial cases and will depend on the surgeon's experience and skill level. A study by Hoekstra and colleagues found a learning curve of 5 to 10 cases to demonstrate proficiency in simple hysterectomy, cuff closure, and pelvic lymph node dissection for gynecologic oncology fellows. Useful methods of teaching were verbal feedback, telestration teaching, and demonstration of a portion of the procedure after a first attempt by the fellow. Looking at hysterectomy performed in a community-based practice, Lenihan and associates found that surgical time stabilized at a total time of 95 minutes after 50 cases.

In a recent study of gynecologic surgeons learning robotic surgery skills, Woelk et al. concluded that “surgical proficiency” with the new techniques required performing many more robotic procedures than previously thought. A total of 325 robotic hysterectomies were done by eight different gynecologic surgeons over a 3-year period at the Mayo Clinic. Operative time and intraoperative and postoperative complications were recorded for each surgeon, and results were analyzed in 6-month blocks of time. Operative time and postoperative length of hospital stay declined significantly over the 3-year study, but complications did not change significantly, although there was a trend toward fewer complications as surgical experience accumulated.

The risk of complications and length of surgery continued to decline and did not level off for any of the surgeons over the 6 to 36 months of evaluation, which included up to 150 hysterectomies for one of the surgeons. None of the surgeons monitored had a complication rate of greater than double the local benchmark rate for abdominal hysterectomy (11.4%), but only one surgeon, the most experienced, was able to achieve a complication rate of less than the abdominal hysterectomy benchmark (5.7%)—and this was finally achieved after 91 robotic hysterectomies. This was the only surgeon who actually did over 90 robotically assisted hysterectomies during the course of the study.

Credentialing Requirements

Credentialing and granting hospital privileging vary throughout the United States. Individual institutions may rely on recommendations from local or national experts for guidelines regarding robotic surgical privileges. The robotic platform is a complex surgical tool, and surgeons should be expected to be specifically credentialed to perform each operation, for example, hysterectomy, using robotic techniques. Credentialing in basic operative laparoscopic skills makes sense, as robotics is an adaptation of laparoscopy. However, advanced laparoscopic skills are not necessarily required or helpful for the robotic surgeon. For experienced surgeons, two to five proctored robotic surgical procedures are usually required

before independent robotic privileges are granted. Residents and fellows will likely have a more protracted exposure to robotics and may require performance or significant involvement in more cases before showing proficiency.

In our institution, credentialing criteria for robotic surgery include core privileges in the specialty (gynecology, urology, general surgery, etc.) with documented attendance at a basic certified course in robotics and observation of a minimum of two full robotic cases before being granted temporary privileges. Documentation of robotic training during residency or fellowship may satisfy the above requirements. Before performing proctored procedures, the surgeon must perform a minimum of two documented simulated runs with OR staff and the robotic instrument specialist. After this, two proctored cases are observed by a physician with robotic privileges. Surgeons are then able to operate independently and must perform a minimum of eight procedures within the next year to maintain robotic privileges. The Department of Obstetrics and Gynecology places the surgeon in a period of focused review for ongoing evaluation of outcomes and patient safety.

How Will Resident Training Be Altered with the Advent of the Robotic Platform?

As the technologic advances in minimally invasive surgical procedures increase, the demands placed on resident training are in constant flux. During the late 1980s, vaginal, simple laparoscopic, and open surgery progressed to incorporate more advanced hysteroscopic and laparoscopic techniques. Eventually, this led to the more common use of total and subtotal laparoscopic hysterectomy. Twenty years later, in an era of robotic surgery, the gynecologic surgeon in training has a wider spectrum of procedures to master in the same 4-year time frame. Will resident physicians graduate with an adequate number of each type of hysterectomy to be proficient? Will it become rare to perform the traditional open abdominal hysterectomy? Will the vaginal hysterectomy be utilized less frequently? How do we teach patient selection for robotic surgery? While robotic surgery may replace abdominal hysterectomy for many indications, vaginal hysterectomy is associated with low morbidity, short operating time, rapid postoperative recovery, and low cost, so it should remain the technique of choice when technically possible.

With regard to resident training in hysterectomy, in the United States, obstetrics and gynecology residents perform an average of 120 hysterectomies during their training. This is an overall decrease in the total number of hysterectomies compared to years past, with a notable decrease in the number of vaginal hysterectomies as reported by Pulliam. Now, with robotic training, there is the potential for a significant decrease in the number of abdominal hysterectomies performed by the average gynecologic surgeon as well as the resident-in-training. In our community, we found that abdominal hysterectomies decreased significantly after robotic surgery became available, but no decrease in vaginal and/or laparoscopic-assisted vaginal hysterectomy was detected.

ROBOT COMPONENTS AND INSTRUMENTATION

Although the da Vinci robotic system is currently the only FDAapproved robotic system for surgery, there are three models currently in use: the original standard unit, the S model, and the Si model. The models vary in instrument length, camera capability, presence of a third operating arm, and the availability of high-definition video capability. Each system consists of the patient-side cart, the surgeon console, and the vision cart/console.

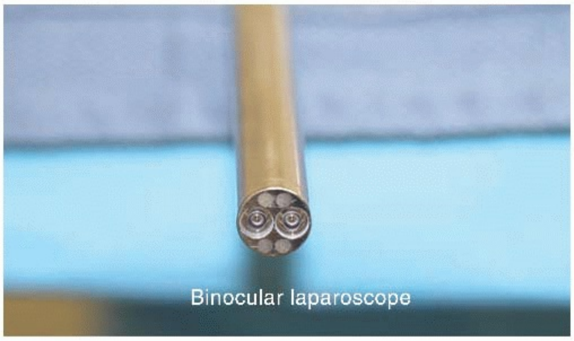

FIGURE 17.1 Binocular, 3D laparoscope.

Vision Cart

A 12-mm endoscope (**Fig. 17.1**) that is passed through the camera port in the patient is internally composed of two 5-mm lenses attached to the camera head, all of which are on the sterile field. The camera cables are passed off the field and attached to the vision system, which processes the images from the two 5-mm lenses and produces the 3D stereoscopic view. In addition to the vision system, the vision cart/console also contains the light source, heated carbon dioxide insufflator, and cautery unit or another energy source (**Fig. 17.2**).

The vision console is usually equipped with a video monitor that provides a 2D view of the operative field and allows telestration. The touch screen monitor allows the table-side assistant, educator, or colleague to draw on the monitor, which projects over the field visualized by the surgeon at the surgeon console. This allows for education of the surgeon, trainee, or members of the surgical team (**Fig. 17.3**). The vision cart is mobile and pulled adjacent to the operating table once the surgical procedure has begun.

Patient-Side Cart

The patient-side cart (**Fig. 17.4**) is placed immediately next to the operating table by either straight docking between the patient's legs or side docking at the level of the right or left hip. The standard system was designed with a camera arm and two operating arms. The S and Si systems have three operating arms and a camera arm. Positioning of the camera arm and operating arms varies with the procedure to be performed. The arms are attached to laparoscopic ports through which the wristed instruments or camera is placed. Without a second surgeon console, only two of the robotic operating arms are

capable of movement at any point in time. If the third arm is docked, one of the arms can serve as a retractor while the surgeon utilizes the other two arms for surgery. The surgeon may alternate or toggle between the available robotic operating arms. Instruments are interchangeable between all three operating arms. Most surgeons will use monopolar scissors for dissection in one arm and a grasper utilizing bipolar cautery, PK, or harmonic shears for hemostasis in the opposite hand.

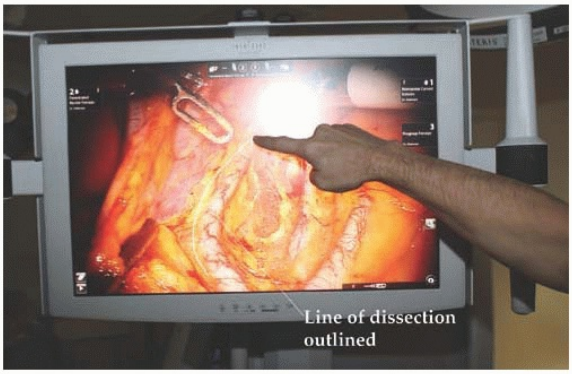

FIGURE 17.2 Vision cart.

FIGURE 17.3 Telestration monitor.

FIGURE 17.4 Patient-side cart.

FIGURE 17.5 S model surgeon console.

Surgeon Console

The surgeon console (**Fig. 17.5**) is composed of a stereoscopic viewer through which the surgeon views the surgical field: two master controllers used to manipulate instruments and move, rotate, and focus the camera and a series of foot pedals. Foot pedals on the right side are used to activate the energy sources for the two operating instruments. A camera pedal on the left side allows movement of the camera. The S system has a pedal to focus the camera and a separate pedal on the left side to switch between two operating arms (**Fig. 17.6**). The Si system does not have a foot pedal to focus the camera, as that function is accomplished with the master controllers. A toggle switch is built into the side of the Si unit that is foot-activated to alternate operating instruments (**Fig. 17.7**). As mentioned earlier, the Si system allows a second surgeon at a separate console to operate in parallel with the primary surgeon by controlling the third operating arm. In addition, the Si system allows visualization of radiographic images by the surgeon in the surgeon console display. While the surgeon sees intraoperative images in high definition and three dimensions, the OR staff sees conventional images on the accessory monitors. The Si unit also allows for a teaching/simulation unit to be attached and operated from the surgeon console.

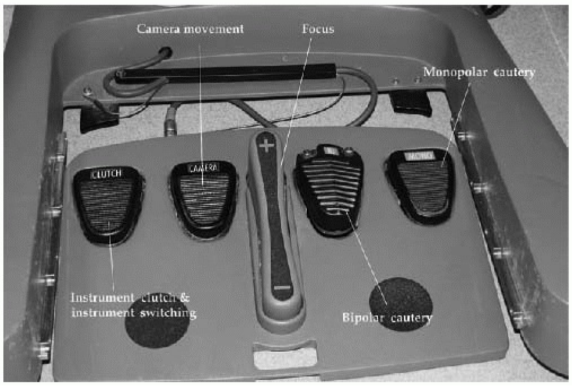

FIGURE 17.6 S model foot pedals.

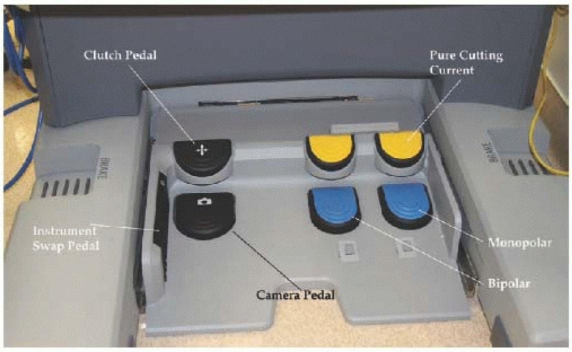

FIGURE 17.7 Si model foot pedals.

Instruments

A variety of interchangeable instruments (**Fig. 17.8**) specific to robotic surgery are available for use. As mentioned previously, most surgeons will utilize scissors with monopolar cautery in one operating arm and a grasper with attached energy source for hemostasis in the opposite arm. A fenestrated grasper is available for the third arm. Additional instruments include vascular forceps, a single-tooth tenaculum, a monopolar spatula, and several types of needle drivers. Each da Vinci-specific instrument may be reused up to 10 times. The table-side assistant may use a laparoscopic atraumatic grasper, irrigator/aspirator, energy source, and needle driver through the right or left upper quadrant assistant port. If a hysterectomy is performed for reasons other than cervical cancer, most surgeons will utilize a uterine manipulator. Two popular manipulators are the RUMI system (CooperSurgical, Trumbull, CT) with Koh ring or a VCare Manipulator (ConMed EndoSurgery, Utica, NY). If manipulating the cervix is contraindicated, the Apple vaginal probe (Apple Medical Corp, Marlborough, MA) is helpful (**Fig. 17.9**).

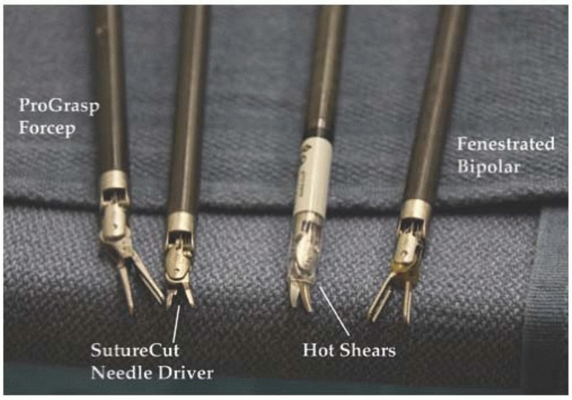

FIGURE 17.8 Commonly used robotic instruments.

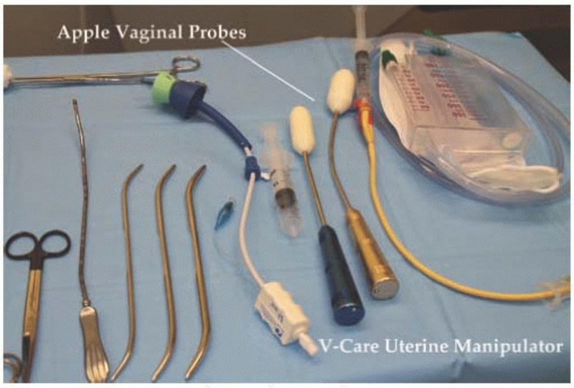

FIGURE 17.9 Uterine and vaginal manipulators.

Energy Sources

The use of an energy source for tissue dissection and cutting will usually involve monopolar electrocautery with a da Vinci scissor or spatula. Bipolar cautery may be applied with a fenestrated forceps or Maryland dissector. Additional energy sources used with robotic instruments include Harmonic ACE (ultrasonic shears) (Ethicon Endo-Surgery, Cincinnati, OH) and the Gyrus PK dissecting forceps (advanced bipolar) (Gyrus ACMI, Maple Grove, MN).

OR AND TABLE SETUP

If possible, the largest available OR should be assigned as home for the robotic system. Sufficient room must be allowed for the operating table to be positioned for a variety of cases involving the pelvis, upper abdomen, thorax, and head and neck region. The patient-side cart and vision cart are mobile and parked away from the operating table until needed. Once needed, they are positioned adjacent to the operating table for surgery. Gynecology cases will involve two operating table setups: one for placing vaginal instruments and one larger table for the abdominal portion of the procedure (**Figs. 17.10** and **17.11**). Most operating tables currently in use will allow for patient weight in excess of 600 pounds and 30 degrees of Trendelenburg position. To avoid movement of the patient in steep Trendelenburg position, the table should be equipped with a warmed gel pad allowing for friction with the patient's bare skin or a beanbag device, which molds to the patient (**Figs. 17.12** and **17.13**). Another option is an inverted egg

mattress taped to the bed for bare skin contact (**Fig. 17.14**). The patient's arms are padded with foam, tucked to her side, and secured with bedsheets. Shoulder braces may be used with care to prevent movement of the patient (**Fig. 17.15**). If not positioned carefully, the shoulder braces may put the patient at risk for nerve injury. Adjustable stirrups in standard and bariatric sizes are needed to allow placement of vaginal instruments. With motion of the camera arm, there is risk of contact with the patient's face, resulting in injury. Padding of the patient's face will be addressed in the anesthesia section.

FIGURE 17.10 Mayo stand setup.

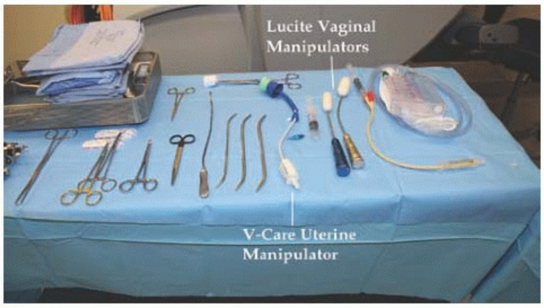

FIGURE 17.11 Vaginal table setup.

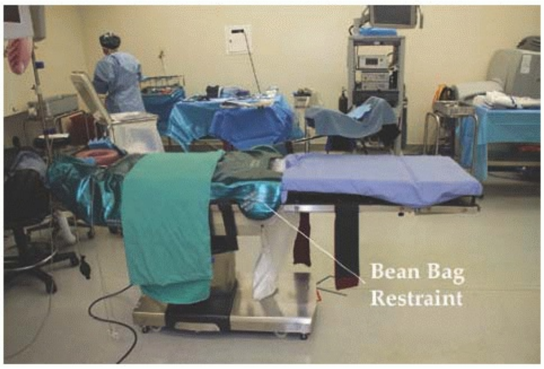

FIGURE 17.12 Beanbag restraint.

FIGURE 17.13 Gel pad restraint.

FIGURE 17.14 Inverted egg crate mattress restraint.

FIGURE 17.15 Shoulder brace.

Anesthetic Considerations

Anesthetic concerns regarding OR procedures for robotic surgeries include the use of steep Trendelenburg, tucking and padding both arms, covering both legs, and padding and covering the patient's face. Airway pressures may be elevated due to increasing patient size and steep Trendelenburg positioning. Intra-abdominal pressures created by carbon dioxide insufflation and intestines resting on the diaphragm can create an anesthetic challenge. Over time, surgeons and anesthesiologists have become more comfortable with these challenges. When our program started, all patients had two large bore intravenous (IV) sites, and in many cases, an arterial line was placed. Currently, invasive monitoring is seldom needed, and in most cases, a single IV site is utilized. We have made an effort to assess all patients in the preanesthesia clinic several days prior to surgery, therefore providing the safest possible surgery and anesthetic experience. Many gynecologic procedures will involve placing a laparoscopic port in the left upper quadrant of the abdomen for use by the first assistant. We routinely place an orogastric tube to decompress the stomach and avoid gastric trauma from port placement. An important anesthetic consideration is knowing that gastric secretions may track along the orogastric tube to fill the mouth or stain the patient's face. As mentioned earlier, the camera arm of the robot is in constant motion and may come in contact with the patient's face, especially when the camera port is placed well above the umbilicus or a 30-degree, downward lens is used. To prevent trauma, eye shields are placed on the patient; followed by foam padding; and then a face shield allows egress of the endotracheal tube, esophageal stethoscope, and orogastric tube (**Fig. 17.16**). In cases of lymphadenectomy, the IV fluid rates are kept at a minimum by anesthesia to avoid venous distention.

The Dedicated OR Team

As the surgeon is sitting at the surgeon console without patient contact, he or she relies exclusively on the dedicated OR team to be the hands and eyes at the table. Dedicated

implies two definitions: team members who are personally committed to the most efficient and safe robotic procedures possible, and OR management that will assign the same skilled staff for all cases rather than rotating multiple OR staff. Members of our team include a circulating registered nurse familiar with the variety of robotic procedures, driving the patient-side cart and troubleshooting any problems with console error messages and instrument needs. In addition, we utilize two table-side assistants, one of whom will provide retraction, pass instruments or suture, irrigate the field when needed, and address any conflicts between robotic arms. The second table-side assistant is responsible for uterine manipulation and specimen retrieval (**Fig. 17.17**). Both assistants drape the upper abdomen while the surgeon places the uterine manipulator. The two bedside assistants may be surgical scrub technicians, certified surgical first assistants, physician assistants, nurse practitioners, or resident physicians. The most efficient operations will be associated with the most experienced table-side assistants.

FIGURE 17.16 Eye protection and facial padding.

The Surgeon

In addition to operating the instruments, the surgeon has several other important perioperative responsibilities. The surgeon is responsible for assuring a reasonable period of time for the initial learning curve, appropriate patient selection, preoperative preparation of the patient, and calm leadership of the rest of the team. There are several possible definitions of the “learning curve” for robotic surgery. It may be defined as the length of time or number of cases to reach a predictable operating time, the fewest complications, or lowest blood loss. It is not in the patient or surgeon's best interest to start with the most complicated procedures. Dealing with a morbidly obese patient, multiple previous abdominal procedures, large fibroid tumors of the uterus, or severe pelvic endometriosis while still learning to effectively manipulate the robotic instruments will result in more complications, unnecessarily long surgical times, and surgeon frustration. Accommodating to the use of different surgical instruments and the lack of haptic sensation is best dealt with by scheduling less complicated cases at the onset of training. Once appropriate patient selection has been completed, the surgeon should explain the aspects of surgery and provide detailed postoperative instructions in advance of the surgery. We have been emphatic about the need to avoid straining or Valsalva maneuvers in the first 2 weeks postoperatively and avoiding any vaginal sexual intercourse for 6 weeks following surgery. On the basis of the type of procedure planned, the surgeon will decide on placement of the camera port, first-assistant port, and two or three operating ports. The operating table will be positioned to allow either side docking or docking between the patient's legs. The surgeon will place the uterine manipulator and, in many cases, place sutures in the cervix if a hysterectomy is planned. The surgeon will tell the table-side assistant which instruments and energy sources will be needed. Once the patient is in Trendelenburg position and ports are in place (**Figs. 17.18** and **17.19**), the robot is docked and instruments are placed.

At that point, the surgeon assumes control of the surgeon console and initiates the internal portion of the procedure. Once the procedure is complete, the robot is undocked, the abdomen is deflated, and port site skin incisions are closed. Using noncutting trocars, for the 8-mm and 12-mm ports, we have not routinely closed the fascial incisions. All incisions are injected with local anesthetic.

FIGURE 17.17 Surgical assistants' positioning.

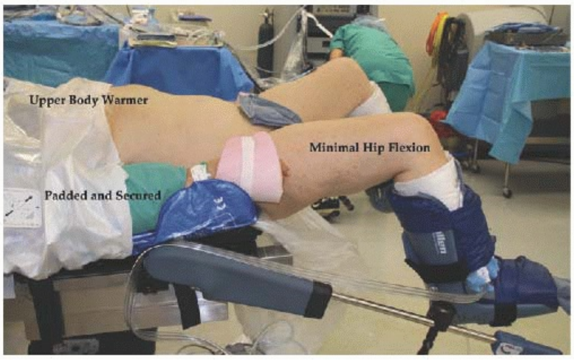

FIGURE 17.18 Patient positioned and padded.

FIGURE 17.19 Ports in place and 30 degrees of Trendelenburg.

Postoperative Care

One of the greatest advantages of minimally invasive surgical procedures, whether laparoscopic or robotic assisted, is the early mobility and dismissal of patients. At the completion of the procedure, if renal function is normal and the patient is well hydrated, IV ketorolac is given before leaving the OR. A 1- to 2-L bolus of intravenous fluids is given in the recovery room, and the Foley catheter is removed prior to discharge from the recovery room. Regular diet, oral analgesics, and IV ondansetron are part of the routine postoperative orders. Patients are discharged home once they are able to tolerate a liquid diet, demonstrate adequate pain control, and void without difficulty. More than 50% of patients can be dismissed the day of surgery and more than 95% dismissed in less than 24 hours after the surgery is complete.

GYNECOLOGIC PROCEDURES PERFORMED ROBOTICALLY

Although many types of gynecologic procedures have been performed, we will focus on the five most common: robotic hysterectomy, robotic hysterectomy and staging lymphadenectomy, robotic radical hysterectomy, robotic myomectomy (RM), and robotic sacrocolpopexy (RSCP). The first report of uterine horn reanastomosis in an animal model was reported by Margossian in 1998, followed by a pilot study by Falcone and colleagues applying robotic surgery for tubal reanastomosis in humans in 2000. In 2002, Diaz-Arrastia and colleagues at the University of Texas Medical Branch in Galveston reported 11 patients undergoing robotic hysterectomy and bilateral salpingo-oophorectomy. Blood loss ranged from 50 to 1,500 mL, and operative times ranged from 4.5 to 10 hours. By 2006, Reynolds and Advincula reported their experience with 16 patients: 12 undergoing robotic-assisted laparoscopic hysterectomy and 4 treated with supracervical hysterectomy. Blood loss ranged from 50 to 300 mL, and operative times ranged from 170 to 432 minutes. Following these initial publications, multiple institutions and investigators have reported their experience with robotic hysterectomy or comparisons among robotic hysterectomy, laparoscopic hysterectomy, and abdominal hysterectomy. These experiences will be listed in detail later. To date, no randomized trials have compared these techniques, although a multi-institutional, international trial to compare abdominal radical hysterectomy to laparoscopic or robotic radical hysterectomy for early-stage cervical cancer has been proposed by Obermair.

Hysterectomy for Benign Indications

Following the initial feasibility studies noted previously, a 2007 study by Kho and associates reported the initial experience with 91 patients undergoing robotic-assisted hysterectomy with or without removal of adnexa, appendix, and lysis of adhesions. Estimated blood loss was 78 mL, mean operating time was 127 minutes, average length of stay was 1.35 days, and a complication rate of 8% was reported. A study by Matthews and another by Landeen compared robotic hysterectomy to laparoscopic hysterectomy and open hysterectomy. Reports by Payne, Shashoua, Nezhat, and Giep have compared robotic hysterectomy to laparoscopic hysterectomy. Table 17.1 summarizes several published reports of robotic hysterectomy for benign indications. In general, robotic hysterectomy was associated with a longer operating time, lower blood loss, similar to shorter length of stay, and similar complication rates when compared to laparoscopic hysterectomy. When compared to abdominal hysterectomy, surgery times were longer, blood loss was lower, length of stay was shorter, and complication rates were lower for patients treated with robotic hysterectomy. It should be noted that all of these studies were retrospective in design. Open hysterectomy and laparoscopic hysterectomy used for comparison were performed prior to the introduction of robotic hysterectomy.

In a study of 256 patients undergoing robotic hysterectomy with uteri weighing 250 to 3,020 g, with the median weight at 453 g, Payne et al. reported median operating times of 167 minutes for women with uteri weighing 500 g or greater, compared to 126 minutes for women with uteri weighing less than 500 g. Blood loss increased as uterine size increased, hospital length of stay was 1 day, and a major complication rate of 2% was reported.

Surgical Technique of Robotic Hysterectomy

STEPS IN THE PROCEDURE

Robotic Hysterectomy with or without Bilateral Salpingo-oophorectomy

- Preoperative assessment including history and physical examination with review of indications for surgery. Assessment in the preanesthesia clinic if indicated. Equally important is the assessment for the robotic approach, including patient size; associated medical conditions, which may impact the ability to tolerate steep Trendelenburg positioning; and ventilation.
- Following induction of anesthesia, placing a temporary Foley catheter, cervical sutures, and uterine manipulator if planned for use will complete the vaginal portion.
- Camera port positioning well above (25 cm) the fundus of the uterus to allow an unobstructed field of view is essential. Operating ports and first-assistant ports are placed after insufflation with CO_2 to assure there is no external conflict/contact between arms.
- The patient is placed in the maximum Trendelenburg position required for the procedure, and the patientside cart is docked.

- The retroperitoneum is developed on each side to allow optimal visualization of the ureters. If salpingo-oophorectomy is planned, the ovarian vasculature is coagulated/sealed and divided. If the adnexa are to be preserved, the utero-ovarian ligaments are coagulated and divided.
- The uterus is placed under traction to one side, and the peritoneum of the anterior and posterior broad ligament is incised to skeletonize the uterine vasculature adjacent to the cervix.
- The anterior peritoneum and bladder are dissected away from the cervix and bladder to allow visualization of the impression of the colpotomy ring of the uterine manipulator distending the anterior vaginal fornix.
- The uterine vessels are coagulated/sealed at the level of the colpotomy ring with the bladder gently displaced distally.
- An anterior colpotomy is created on top of the colpotomy ring and extended circumferentially around the vaginal fornix allowing the uterus and cervix to be detached from the vagina and delivered through the colpotomy.
- A damp laparotomy sponge is placed in the vagina to prevent loss of CO_2, and the field is assessed for hemostasis.
- The vaginal angles are secured, and the vaginal cuff is closed with running or interrupted absorbable suture placed 1 cm back from the edge of the vagina to minimize cuff dehiscence.
- After the abdominal incisions are closed, the vaginal pack is removed and the vagina is inspected for evidence of any lacerations or bleeding.
- Orders are placed to remove the Foley catheter in the recovery room and start the patient on oral analgesics, regular diet, and most will be dismissed the same day.
- Patients are instructed to avoid vaginal intercourse for seven weeks postoperatively.

On the day prior to surgery, we have requested patients limit themselves to a full liquid diet and take one bottle of magnesium citrate at noon.

TABLE 17.1 Robotic Hysterectomy Compared to Laparoscopic and Abdominal Routes

AUTHORS	NO. OF SUBJECTS	EBL MEAN (RANGE)	OPERATIVE TIME MINUTES MEAN (RANGE)	LOS	COMPLICATION RATE (%)
Diaz-Arrastia et al. (2002)	11	50-1,500 mL	4.5-10 h		
Reynolds and Advincula (2006)	16	*96* (50-300)	242 (170-432)		
Kho et al. (2007)	91	78	127	1.35 ± 0.69	8
Payne et al. (2008)	100	61 ± 60	119 ± 59	1 ± 0.7	
Shashoua et al. (2009)	26	113 (50-300)	142 (90-218)	1.0 (0-2)	
Boggess et al. (2009)	152	79 ± 132	122 ± 48	1.05 ± 0.69	3.50
Nezhat et al. (2009)	26	250 (100-1,000)	276 (150-440)	1.0 (1-1)	
Giep et al. (2010)	237	59 ± 75	89 ± 37.5	1.0 ± 0.1	3.80
Matthews et al. (2010)	65	82 ± 106	NL	1.5 ± 0.7	4.20
Payne et al. (2010)	256	98 ± 106	151 ± 57	1.1 ± 0.7	3.50
Feuer et al. (2011)	55	63.5 ± 3.76	80.9 ± 3.4	1.3 ± 0.15	1.80
Landeen et al. (2011)	569	109 ± 143	117 ± 59	1.3 ± 0.6	8.40
Laparoscopic Hysterectomy					
Payne et al. (2008)	100	113 ± 85	92 ± 29	1.6 ± 1.4	
Shashoua et al. (2009)	44	98 (50-450)	122 (60-245)	1.4 (0-5)	
Nezhat et al. (2009)	50	300 (110-750)	206 (110-420)	1.05 (1-3)	
Giep et al. (2010)	265	167 ± 146	124 ± 48	1.2 ± 0.7	1.90
Matthews et al. (2010)	21	353 ± 303	NL	1.8 ± 0.8	6.80

Feuer et al. (2011)						
Landeen et al. (2011)	227	182 ± 185	118 ± 45		1.8 ± 1.5	8.80
Abdominal Hysterectomy						
Matthews et al. (2010)	113	430 ± 417			3.5 ± 3.2	23.40
Feuer et al. (2011)						
Landeen et al. (2011)	274	269 ± 385	83 ± 33		2.7 ± 1.4	14

EBL, estimated blood loss; LOS, length of stay.

Prior to induction of general anesthesia, the patient is positioned on the operating table utilizing a gel pad, inverted egg crate mattress, or beanbag positioner. Depending on the patient's size, shoulder braces may be needed but used with caution. Once the patient is anesthetized, prepped, and draped, an indwelling catheter is placed in the bladder and sutures of size 0 polyglactin are placed at the 3 o'clock and 9 o'clock positions in the cervix. The cervix is dilated, and a uterine manipulator is placed. We prefer to use the VCare Manipulator (ConMed EndoSurgery, Utica, NY). The sutures are brought through the colpotomy ring for traction to allow removal of the uterus later. The abdomen is then approached, and a decision regarding camera port placement is made. In virtually all cases, the camera port is above the umbilicus; however, the distance from the umbilicus depends on the uterine size. A distance of 20 to 24 cm above the uterine fundus is ideal. Once the abdomen is insufflated, sites are marked for the additional ports. Eight-millimeter ports for the operating arms are usually placed 10 cm lateral to the midline at or just below the level of the umbilicus. A 12-mm port is placed for the first assistant in the left upper quadrant, and an additional 8-mm port for the third operating arm of the robot is placed in the right lower quadrant (**Figs. 17.20** and **17.21**). The patient is placed in 30 degrees of Trendelenburg, and the bowel is displaced from the pelvis. Conventional laparoscopic instruments may be needed for dissection of omental and bowel adhesions to enhance port positioning and visualization. The robotic arms are then docked to the ports, and instruments are placed. We usually use a fenestrated bipolar grasper in one operating port and monopolar scissors in the opposite port. A Prograsp forceps is frequently placed in the third operating port. The first assistant uses an atraumatic grasper, bariatric needle driver, and irrigator/aspirator through the 12-mm port in the left upper quadrant.

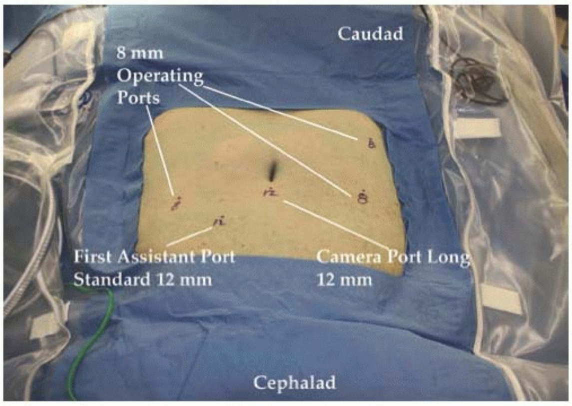

FIGURE 17.20 Port site marking.

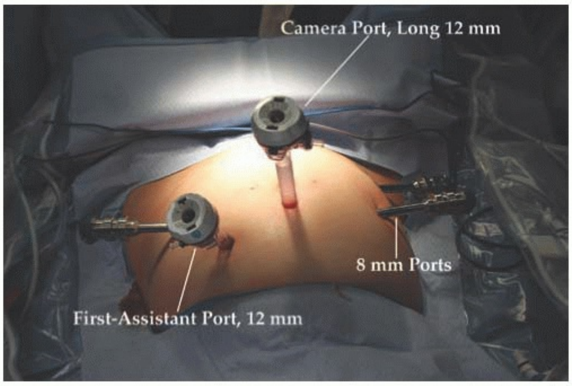

FIGURE 17.21 Ports in place.

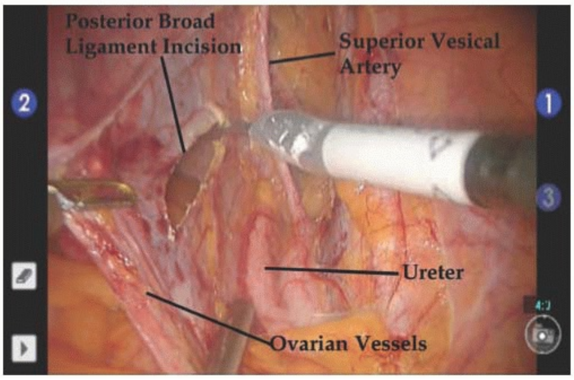

FIGURE 17.22 Incising the posterior broad ligament.

The technical steps in a hysterectomy follow those of a standard abdominal hysterectomy except for entry into the vagina. The uterus is grasped at the cornua and displaced to one side with the Prograsp forceps that runs parallel to the anterior abdominal wall. Once the ureter is identified in the retroperitoneum (**Fig. 17.22**), the round ligament is coagulated and divided. If salpingo-oophorectomy is planned, the ovarian vasculature is coagulated and divided at this time (**Fig. 17.23**). The anterior and posterior broad ligaments are incised, and uterine vasculature is then skeletonized and coagulated (**Fig. 17.24**). The uterine artery can be coagulated at the level of the hypogastric artery to minimize bleeding if extended dissection of the uterus due to leiomyoma or endometriosis is anticipated (**Fig. 17.25**). Once the above procedures have been completed on both sides, the bladder is dissected clear of the uterus and cervix, allowing identification of the colpotomy ring distending the anterior vaginal fornix (**Fig. 17.26**). With the bladder well dissected and displaced inferiorly, the anterior colpotomy is made and carried circumferentially around the vaginal fornix on top of the colpotomy ring (**Fig. 17.27**). When completely detached, the uterus and cervix (and adnexa if included) are delivered through the vagina. At this point, the bedside assistant will place a dry laparotomy sponge within a sterile surgical glove to occlude the vagina, thus preventing loss of carbon dioxide (**Fig. 17.28**). Monopolar scissors are replaced with a needle driver, and the vaginal cuff is closed. A 0 polyglactin suture in either an interrupted figure-of-eight placement or running from each angle to the midline is used to close the vaginal apex (**Fig. 17.29**). Support is provided by incorporation of the cardinal and uterosacral ligaments into the angle closure. In the case of uterine leiomyomata, which prevents delivery of the uterus through the vagina, we secure the uterus with the third operating arm while bivalving or quartering the uterus with monopolar cautery. Once all vascular pedicles are inspected, the instruments are removed, the robot undocked, the abdomen deflated, and ports removed. As we use only noncutting trocars, none of the fascial incisions are closed. All incisions are injected with 0.25% bupivacaine with epinephrine following subcutaneous closure and before applying a liquid skin adhesive. In the absence of contraindications, we will give 15 to 30 mg of ketorolac intravenously at the end of the case and 1 to 2 L of IV fluid in the recovery room. Oral analgesics are prescribed once dismissed from the recovery room. Most patients will be discharged home within 24 hours with instructions to ambulate frequently, avoid straining for 2 to 3 weeks, and avoid sexual intercourse for 6 weeks.

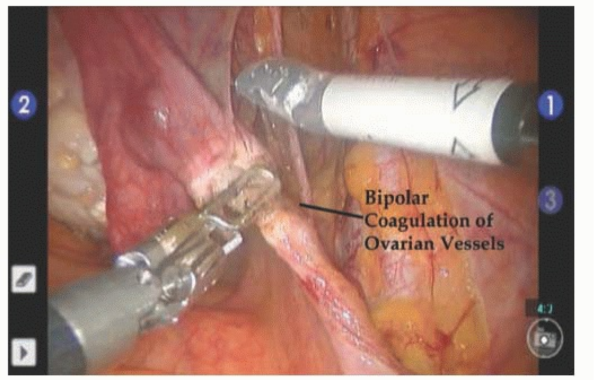

FIGURE 17.23 Coagulation of ovarian vessels.

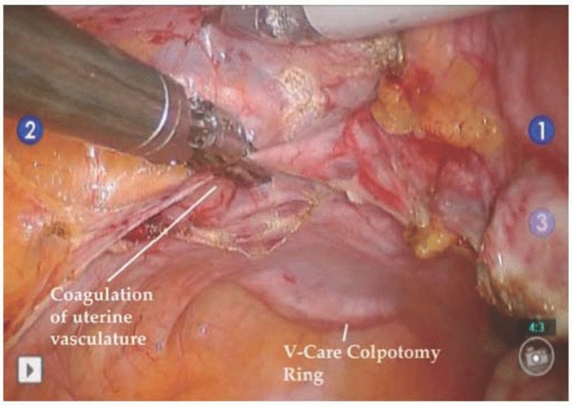

FIGURE 17.24 Coagulation of uterine vessels.

Robotic Hysterectomy and Lymphadenectomy for Endometrial Cancer

Perhaps, the area of gynecologic surgery most enthusiastically adopting robotic techniques is in treatment of endometrial cancer. Because of age, health issues, and size, this group of women represents the highest risk for surgical complications. Table 17.2 represents most of the available literature regarding the application of robotic surgery for treatment of uterine cancer. Studies by Boggess, Bell, and Lim compare hysterectomy and staging lymphadenectomy performed robotically, laparoscopically, or as an open procedure. In general, blood loss and length of postoperative hospitalization were the lowest in the robotic group. Operating times were shortest in the open group and comparable in the robotic and laparoscopic groups. Complications were lowest in the robotic group. Lymph node counts were similar across all three groups. Studies by Seamon, Holz, and Cardenas-Goicoechea compare hysterectomy and staging lymphadenectomy performed robotically with those performed laparoscopically. Surgical time was shorter, and length of stay for robotic surgeries was shorter in two of the three studies. Estimated blood loss was lower for robotic surgery in all three studies. Node counts were higher in the robotic group in one study and comparable in the other two studies. Conversion to an open procedure was less likely in the robotic group compared to the laparoscopy group. Studies by Veljovich and DeNardis comparing robotic hysterectomy and staging lymphadenectomy to an open procedure confirm that operating times are longer, blood loss is less, and length of stay is shorter in the robotic group. Node counts are comparable in both groups.

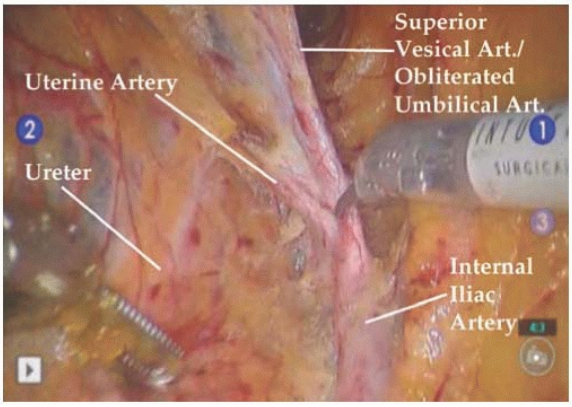

FIGURE 17.25 Visualization of uterine artery.

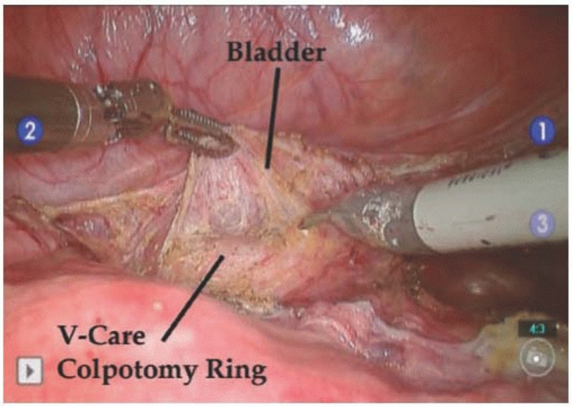

FIGURE 17.26 Bladder dissection.

Because of the association between obesity and endometrial cancer, the role of robotic surgery in that patient group is of great interest. Gehrig and colleagues reported on 49 obese patients with endometrial cancer treated robotically compared to 32 matched patients treated laparoscopically. Robotic surgery was associated with a lower estimated blood loss, shorter operating times, shorter hospital stay, and increased node counts. When comparing robotic surgery for endometrial cancer in the obese patient to an open procedure, Seamon and colleagues demonstrated lower blood loss, fewer complications, shorter length of stay, and comparable node counts with robotic surgeries. However, longer operating times were also reported for the patients treated robotically. To date, there are no prospective studies comparing robotic hysterectomy and staging lymphadenectomy to laparoscopic or open approaches.

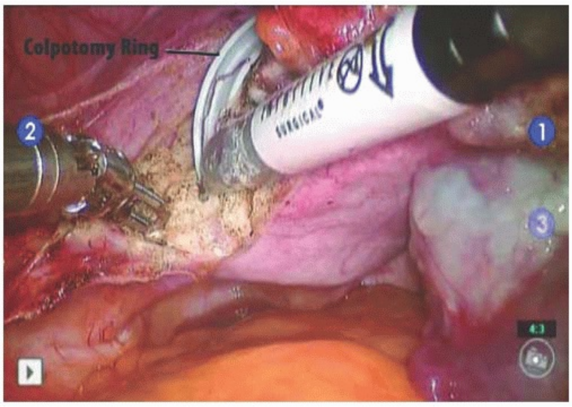

FIGURE 17.27 Colpotomy.

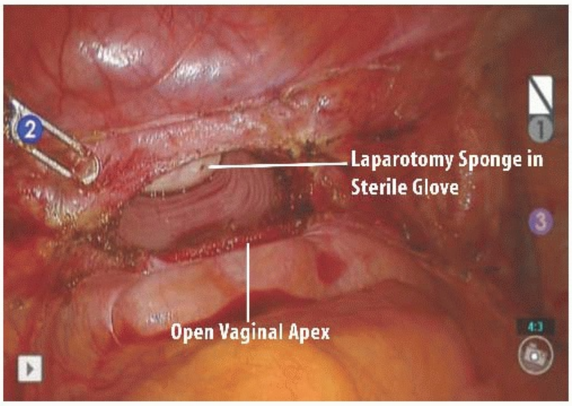

FIGURE 17.28 Open vaginal cuff.

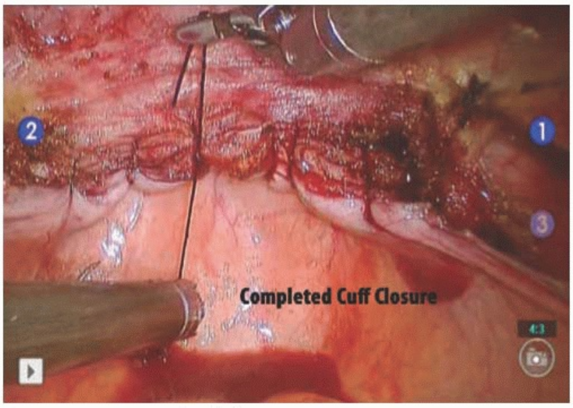

FIGURE 17.29 Vaginal cuff closure.

TABLE 17.2 Hysterectomy and Staging Lymphadenectomy

ROBOTIC TECHNIQUE

AUTHORS	NO. OF SUBJECTS	EBL MEAN ± SD OR (RANGE)	OPERATIVE TIME MINUTES MEAN (RANGE)	NO. OF NODES	LOS	COMPLICATION RATE (%)
Boggess et al. (2008)	103	74 ± 101	191 ± 36	32 ± 26	**1 ± 0.2 d**	
Veljovich et al. (2008)	25	*66* (10-300)	283 (171-4,430	17 (2-32)	40 h (17-215)	
DeNardis et al. (2008)	*56*	105 ± *77*	*177* ± *55*	18.6 ± 12	1.0 ± 0.5 d	
Bell et al. (2008)	40	166 ± 225	184 ± 41	17 ± 7.8	2.3 ± 1.3	7.50
Gehrig et al. (2008)	49 (obese)	50 (25-300)	189 (111-263)	31 (6-73)	1.02 (1-2)	
Lowe et al. (2009)	405	87 ± 97	170 ± 68	*15.5* ± *9.6*	1.8 ± 2.8	
Holloway et al. (2009)	100	103 ± 80	171 ± 50	18.7 ± 11	1.2 ± 0.93	
Seamon et al. (2009)	105	88 (20-500)	242 ± 53	31 ± 7.6	1 (1-46)	13
Seamon et al. (2009)	92 (obese)	109	228 ± 43	24.7 ± 13.2	1 (1-2)	11
Lim et al. (2010)	*56*	89 ± 45	162 ± 53	26 ± 12	1.6 ± 0.7	12

Cardenas-Goicoechea et al. (2010)	102	109 ± 83	237 ± *57*	22 ± 10	1.88 ± 1.167	7.80
Holz et al. (2010)	13	84.6 ± 32	192 ± 38	13 ± 4.5	1.7 ± 0.6	15
Lim et al., 2011	122	81 ± 45	147 ± 48	25 ± 12.7	1.5 ± 0.9	10.50
Laparoscopic Technique						
Boggess et al. (2008)	81	145 ± 105	213 ± 34	23 ± 11	1.2 ± 0.5 d	
Bell et al. (2008)	30	253 ± 427	171 ± 36	17 ± 7.1	2.0 ± 1.2	20
Gehrig et al. (2008)	32 (obese)	150 (50-700)	215 (156-324)	24 (3-59)	1.27 (1-4)	
Seamon et al. (2009)	*76*	200 (50-650)	287 ± 55	33 ± 8.4	2 (1-9)	14
Lim et al. (2010)	*56*	209 ± 91	192 ± *55*	45 ± 20	2.6 ± 0.9	23
Cardenas-Goicoechea et al. (2010)	173	187 ± 187	178 ± 58	23 ± 12	7.50	
Holz et al. (2010)	20	150 ± 111	156 ± 49	8.5 ± 5.4	15	
Lim et al. (2011)	122	207 ± 109	186 ± 59	43 ± 17	3.2 ± 2.3	19.60
Abdominal Technique						
Boggess et al. (2008)	138	266 ± 184	146 ± 48	14.9 ± 11	4.4 ± 2.0 d	
Veljovich et al. (2008)	131	197 (25-900)	139 (69-294)	13 (1-42)	127 h (13-576)	
DeNardis et al. (2008)	106	241 ± 115	79 ± 17	18 ± 9.6	3.2 ± 1.2	
Bell et al. (2008)	40	316 ± 282	108 ± 41	15 ± 4.8	4.0 ± 1.5	27.50
Seamon et al. (2009)	162 (obese)	394	142 ± 47	23.9 ± 11.8	3 (3-4)	27
Lim et al. (2010)	36	266 ± 145	136 ± 32	55 ± 23	4.9 ± 1.9	25

EBL, estimated blood loss; LOS, length of stay.

Surgical Technique for Lymphadenectomy

We prefer to perform the pelvic lymphadenectomy prior to the hysterectomy and the aortic node sampling after the hysterectomy. By developing the retroperitoneum, including the paravesical and pararectal spaces, the medial leaf of the broad ligament serves as a barrier between the node-bearing tissues and the rectosigmoid. The extent of the lymph node dissection in the pelvis includes the distal common iliac nodes, the nodes surrounding the external iliac artery and vein, and the obturator lymph nodes (**Fig. 17.30**). At the completion of the pelvic lymphadenectomy, all nodal tissues from both sides are placed in a sterile plastic pouch to be delivered through the vagina at the completion of the hysterectomy. The hysterectomy is performed as described previously. Once the vaginal cuff is closed, the monopolar scissors replace the needle driver and the right-sided aortic node sampling is performed. The peritoneum overlying the right common iliac artery is incised to the level of the lower aorta and inferior mesenteric artery. The nodal tissue overlying the lower aorta and distal vena cava is dissected clear of those vessels while retracting the right ureter laterally (**Fig. 17.31**). The right-sided aortic nodes are placed in the thumb of a sterile glove and brought out through the first-assistant port. The left aortic lymphadenectomy is similar but less difficult because there is no vena cava on the left side. The left ureter should be identified and carefully avoided.

Since less IV fluid is given intraoperatively to minimize venous filling, extra fluid is given in the recovery room prior to transfer. As with the patients undergoing robotic hysterectomy for benign conditions, many patients can be dismissed on the day of surgery and more than 90% of patients are dismissed in less than 24 hours of surgery.

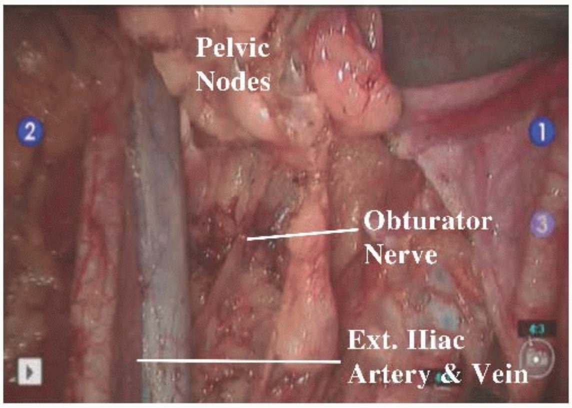

FIGURE 17.30 Pelvic lymphadenectomy.

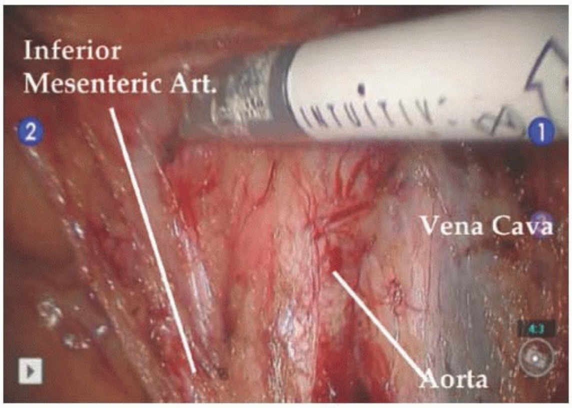

FIGURE 17.31 Aortic node sampling.

Robotic Radical Hysterectomy and Pelvic Lymphadenectomy

Table 17.3 lists 13 studies published since 2008 with a total of 432 patients treated by robotic radical hysterectomy and pelvic lymphadenectomy. Studies by Fanning, Kim, Persson, and Lowe describe the experience of the authors performing the robotic procedure. Five studies by Boggess, Ko, Maggioni, Geisler, and Cantrell compare robotic radical hysterectomy to abdominal radical hysterectomy. Nezhat and Tinelli compared robotic radical hysterectomy to laparoscopic radical hysterectomy. Finally, studies by Magrina and Estape compare robotic radical hysterectomy to laparoscopic radical hysterectomy and abdominal radical hysterectomy. In the study by Magrina, robotic surgery resulted in a decreased length of stay compared to open procedures and comparable length of stay compared to laparoscopic procedures. Operating times for robotic surgery were similar to open procedures but shorter than the laparoscopic approach. Blood loss was greatest in the open group when compared to robotic and laparoscopic techniques. There was no difference in lymph node counts or complications between the three groups. The results reported by Estape differ somewhat in that robotic surgery was longer than open procedures but comparable in length to the laparoscopic approach. Robotic surgery resulted in a higher lymph node count when compared to open and laparoscopic approaches. When looking at the comparative studies of robotic radical hysterectomy to open procedures by Geisler, Maggioni, Cantrell, and Ko, estimated blood loss and length of stay are shorter, operating times in general are longer, and lymph node counts and complications are comparable. There are no prospective studies comparing robotic radical hysterectomy to laparoscopic or open procedures, although an international phase III randomized trial comparing the three approaches has been proposed by Obermair.

Robotic Radical Hysterectomy Technique

Patient positioning for robotic radical hysterectomy is the same as described earlier in the chapter. Uterine manipulators are usually replaced with a Lucite vaginal probe to facilitate dissection of the bladder and to assess the length of the vaginal cuff. Depending on the patient preference, age, and gross appearance, the ovaries may be preserved or removed. Paravesical and pararectal spaces are developed, and the uterine artery is coagulated and divided at its origin from the hypogastric artery. The ureter is then dissected from the medial broad ligament, and the ureteral tunnel is exposed. The anterior vesicle ligament is cauterized and divided, thus unroofing the ureter from the cardinal ligament all the way to its entry into the bladder. Once this has been accomplished on both sides, the bladder is dissected away from the upper third of the vagina, and the posterior vaginal wall and uterosacral ligaments are exposed. The uterosacral ligaments are divided at the level of the anterior rectum. At this point, an upper vaginotomy is performed, and adequate vaginal margin is determined on the basis of the size of the cervical cancer. The specimen is removed through the vagina, and a dry laparotomy sponge in a sterile glove is placed in the vagina to maintain the pneumoperitoneum. Bilateral total pelvic lymphadenectomy is then performed. Common iliac nodes are removed through the first-assistant port and labeled separately. The pelvic nodes are placed in a sterile pouch and brought out through the vagina. The vaginal cuff is closed with interrupted or running 0 polyglactin sutures. Patients are usually dismissed the following morning with an indwelling catheter with plans for a voiding trial in 1 week.

TABLE 17.3 Radical Hysterectomy Comparison

ROBOTIC TECHNIQUE

AUTHORS	NO. OF SUBJECTS	EBL MEAN (RANGE)	OPERATIVE TIME MINUTES MEAN (RANGE)	NO. OF NODES	LOS	COMPLICATION RATE (%)
Boggess et al. (2008b)	51	96 ± 85	210 ± 45	33 ± 14	1	7.80
Magrina et al. (2008)	27	133 ± 108	189 ± 43	26 ± 6.3	1.7 (0.9)	7
Fanning et al. (2008)	20	300 (100-475)	390 (210-510)	18 (15-35)	1 d	10
Kim et al. (2008)	10	355 (200-450)	207 (120-240)	27.6 (12-52)	7.9 (5-17) d	10
Ko et al. (2008)	16	81.9 (20-400)	290 (199-364)	15.6 (4-34)	1.7 (1-4)	18
Nezhat et al. (2008)	13	157 (50-400)	323 (232-453)	24.7 (11-51)	2.7 (1-6) d	30
Persson et al. (2009)	80	150 (25-1,300)	262 (132-475)			
Estape et al. (2009)	32	130 ± 119	144 ± 48	32 ± 10	2.6 ± 2.1	18.80
Maggioni et al. (2009)	40	78 ± 94	272 ± 42	20.4 ± *6.9*	3.7 ± 1.2	5.00
Lowe et al. (2009b)	42	50 (25-150)	215 (120-606)	25 (12-60)	1	16.80
Geisler et al. (2010)	15	165	154	25	1.4 d	
Cantrell et al. (2010)	63	50 (20-400)	213 (73-290)	29 (13-99)	1 (1-3)	4
Tinelli et al. (2011)	23	157 ± 7	323 ± 30	24.7 ± 5	3 ± 1	
Laparoscopic Technique						
Magrina et al. (2008)	31	208 ± 105	220 ± 37	25.9 (7.8)	2.4 (1.5)	6
Nezhat et al. (2008)	30	200 (100-500)	318 (200-464)	31 (10-61)	3.8 (2-11)	205
Estape et al. (2009)	17	209 ± 169	132 ± 42	18.6 ± 5.3	2.3 ± 1.4	23.50
Tinelli et al. (2011)	76	95 ± 5	255 ± 25	27 ± 4.7	4 ± 2	
Abdominal Technique						
Boggess et al. (2008)	49	416 ± 188	247 ± 48	23.3 ± 12.7	3.2	16.30
Magrina et al. (2008)	35	443 ± 253	166 ± 33	27.7 (6.6)	3.6 (1.2)	9

Ko et al. (2008)	32	665 (200-3,500)	219 (113-308)		17.1 (4-38)	4.9 (3-8)	12
Estape et al. (2009)	14	621 ± 194	114 ± 26		25.7 ± 11.5	4.0 ± 1.7	28.60
Maggioni et al. (2009)	40	221.8 ± 132	199.6 ± 65.6		26.2 ± 11.7	5.0 ± 2.4	12.00
Geisler et al. (2010)	30	323	166		26	2.8 d	
Cantrell et al. (2010)	64	400 (100-1,200)	240 (181-420)		24 (4-72)	4 (3-8)	6

EBL, estimated blood loss; LOS, length of stay.

Robotic Use in Reconstructive Pelvic Surgery

Robotic Sacrocolpopexy

The primary application of robotics in reconstructive pelvic surgery has been sacrocolpopexy. Sacrocolpopexy has been the most important operation in the abdominal approach for repair of enterocele and vaginal vault prolapse. It may also be utilized for apical support with concurrent hysterectomy. The procedure is reported by Nygaard as a durable repair with approximately a 90% long-term success rate. Permanent synthetic graft material, usually type I macroporous polypropylene mesh, is used most commonly. In the mid-1990s, the laparoscopic approach to perform this operation was reported by Nezhat and colleagues. However, this was a technically difficult operation to learn with a steep learning curve. Laparoscopic sacrocolpopexy offers similar success rates as open abdominal surgery with the benefits of minimally invasive surgery, such as shorter hospital stay, more rapid recovery, and possibly less morbidity. However, those benefits are associated with longer operating times. Because of the technical difficulties associated with the learning curve and maintaining proficiency as well as the benefits of the vaginal reparative approach, this technique has not been widely adopted. The availability of robotics is changing the trend from the open and laparoscopic approaches.

Several retrospective reports on RSCP or sacrohysteropexy are presented in **Table 17.4.** Akl and associates evaluated 80 patients treated with RSCP and followed them for 1 to 24 months. Five percent of patients required conversion to an open procedure, and a 6% graft exposure rate was reported. Operative time decreased by 25% after the first 10 cases. In three separate studies, Daneshgari, Göçmen, and Kramer describe case series of 12 to 21 patients with overall low blood loss, comparable operative times, and short hospital stays. Kramer described 21 patients who underwent RSCP, with 12 patients requiring additional repairs at a later date.

Reported complications include small bowel obstruction, ileus, pelvic abscess, bladder injury, ureteral injury, and conversion to an abdominal approach. The overall complication rate appears to be no higher than abdominal sacrocolpopexy (ASCP). Geller and colleagues in 2008 reported the largest series but only compared RSCP to ASCP. Geller and colleagues found a significantly longer operating time, shorter length of hospital stay, and lower blood loss for RSCP compared to ASCP. At 6-week follow-up, they reported similar pelvic organ prolapse quantification point C improvement in both groups. Geller and associates treated 28 patients with RSCP at a mean follow-up of 14.8 months. They found improved pelvic floor function with stable support and sexual function. Two patients with graft exposures and two recurrent prolapse were reported. Acknowledging the small volume of published reports, these initial data and unpublished experiences seem to indicate safe and reliable use of the robotic platform for sacrocolpopexy.

TABLE 17.4 Robotic Sacrocolpopexy

AUTHORS	NO. OF SUBJECTS		FOLLOW-UP DURATION	EBL (ML)	OPERATIVE TIME	LOS (DAYS)	OUTCOME
Geller (2008)	73	RSCP	6 wk	103 ± 96	328 ± *55* min	1.3 ± 0.8	Comparable point C improvement
	105	ASCP		255 ± 155	225 ± 61 min	2.7 ± 1.4	
Elliot (2006)	30	RSCP	24 mo (12-36)	3.1 h (2.15-4.75)	1.03 (1-2)		
Akl (2009)	80	RSCP	4.8 mo (1-24)		198 min		Operative time decreased 25% after the first 10 cases
Daneshgari (2007)	12	RSCP	6 mo	81 (50-150)		2.4 (1-7)	
Göçmen (2011)	12	RSCP	12 mo	12.5 (10-20)	150.5 (114-189) min		

Geller (2011a)	28	RSCP	14.8 mo				Pelvic floor function improved
Kramer (2009)	21	RSCP			3 h 14 min	1	

RSCP, robotic sacrocolpopexy; ASCP, abdominal sacrocolpopexy; EBL, estimated blood loss; LOS, length of stay.

Surgical Technique

The initial technical aspects are similar to preparation for hysterectomy as described above. Either a straight or side dock technique is utilized. Port placement for the camera is usually above the umbilicus approximately halfway or higher between the pubic symphysis and xiphoid process (12-mm dilating trocar). Two 8-mm da Vinci dilating trocars are placed approximately 10 cm or greater, lateral to midline at a level usually between the anterior superior iliac spines and umbilicus (below the level of the camera port). The assistant 12-mm port is placed in either the left or right upper quadrant. The third da Vinci robotic arm is not usually required but is prepared for possible additional retraction on more challenging cases. The upper pelvis and abdominal wall are cleared of omental and bowel adhesions with laparoscopy before docking, at which point further adhesions deeper in the pelvis are cleared with the monopolar shears. If the sigmoid colon is excessively redundant or unruly due to poor bowel preparation, it may be retracted to the left anterior abdominal wall with a traction suture to be released at completion of the case. Usually, the assistant is required to retract the sigmoid colon to the left. The vagina is distended with a Lucite probe or large stainless steel bowel sizer (or two as needed) for vaginal manipulation. The rectum also may be stented with a probe to aid in the deep posterior dissection. Other instruments such as Breisky-Navratil retractors may be placed vaginally as needed to improve visualization of dissection planes and suture placement. We will frequently place an Allis clamp in the midline vagina anteriorly and posteriorly where we anticipate placing the most distal aspect of the mesh arms. Placement of the Allis clamps is dependent upon the patient's anatomic defects. Placement of the Allis clamps also helps in identifying how far to extend the dissection in the vesicovaginal and rectovaginal spaces. The upper pelvic structures including the aortic bifurcation, right common iliac artery, right ureter, and sacral promontory are identified. Care is taken to identify the left common iliac vein as it crosses the field. The peritoneum over the first sacral joint (S1) is opened, and the areolar, fatty, and lymphatic tissues are carefully cleared to expose the anterior longitudinal ligament and middle sacral vessels while keeping clear of the left common iliac vein (**Fig. 17.32**).

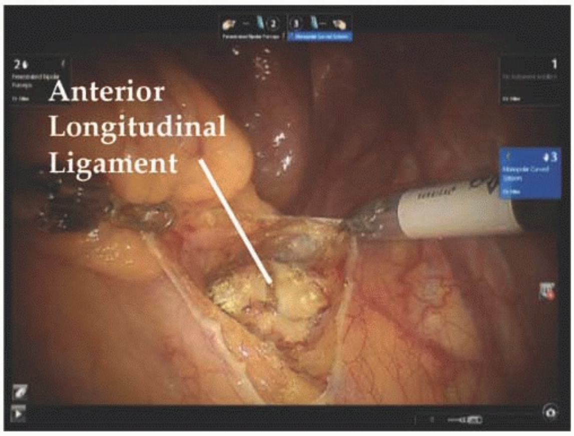

FIGURE 17.32 Exposing anterior longitudinal ligament.

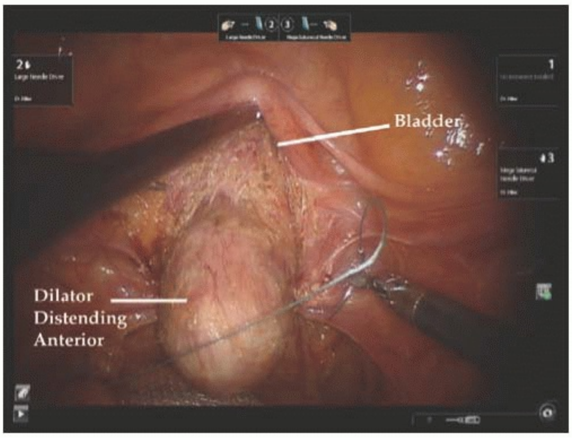

FIGURE 17.33 Exposing anterior vagina.

The middle sacral vessels may be coagulated once skeletonized. A 30-degree downward-directed scope may be helpful for this dissection in some patients. The line of dissection is then carried over the peritoneum and the underlying fatty tissue to the right of the sigmoid colon and medial to the ureter to the pelvic floor and vaginal apex. Care is taken to avoid trauma to the presacral, lateral sacral, and hypogastric veins. Next, the peritoneum over the vagina is opened to develop the rectovaginal and vesicovaginal spaces (**Figs. 17.33** and **17.34**). The table-side assistant is instructed to manipulate the vaginal stent to assist the dissection. Once these spaces are opened and the bladder and rectum are mobilized, an assessment is made of length for the mesh arms. A self-constructed or prefabricated type I macroporous, polypropylene Y-shaped mesh with two arms and a width of 4.5 to 5 cm is cut to the desired length (usually 4 to 8 cm) with a tail for attachment to the sacrum. The mesh is applied over a wide surface area with multiple placements of permanent suture through the full thickness of the vaginal wall. The mesh is attached to the anterior vagina and then the posterior vagina (**Figs. 17.35** and **17.36**). The 30-degree upwarddirected scope may be useful for placement of the low posterior sutures. The vagina is then elevated toward S1, is taken off of tension, and marked for attachment to the anterior longitudinal ligament with a permanent suture placed transversely, usually under the middle sacral vessels. The tail is secured with two or three sutures (**Fig. 17.37**). The peritoneum is then closed over the mesh with a delayed absorbable suture to cover the bridge of mesh between vaginal apex and sacrum in an attempt to decrease the risk of adhesions and bowel obstruction. We close the peritoneum from distal to proximal, taking care not to kink or damage the ureter during the closure. A vaginal pack may be used to keep the vagina distended against the mesh. Antibiotic irrigation may also be used to irrigate the mesh.

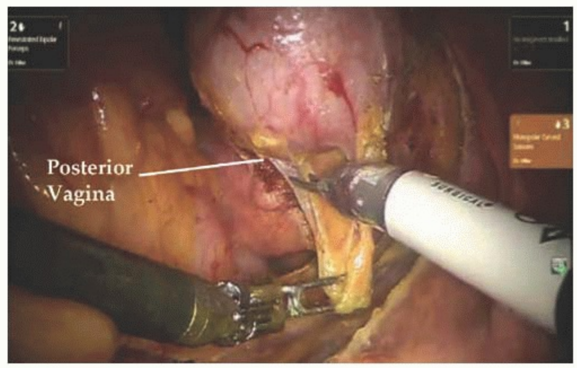

FIGURE 17.34 Exposing posterior vagina.

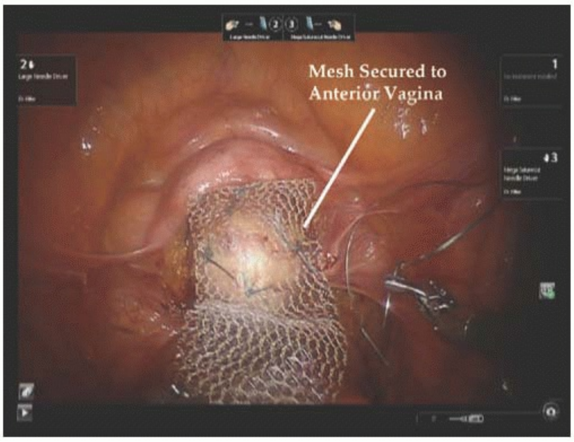

FIGURE 17.35 Mesh secured to anterior vagina.

Robotic Burch Retropubic Urethropexy

There are currently no studies looking specifically at the use of robotic retropubic urethropexy, although three patients undergoing the procedure are mentioned in reports by Partin and Daneshgari. This surgical procedure is primarily utilized in conjunction with RSCP for the treatment of overt or occult stress incontinence especially with urethrovesical junction hypermobility or urethrocele. The major obstacle to overcome is the lack of tactile sensation for placing the periurethral sutures. The advantages of laparoscopic retropubic urethropexy (LRPU) and robotic Burch retropubic urethropexy are improved hemostasis, visualization, and accurate, symmetric suture placement and tensioning. Paravaginal repair for additional lateral midvaginal support may also be placed.

Surgical Technique

The technique is initially the same as performing an LRPU (Marshall-Marchetti-Krantz procedure or Burch procedure). With a Foley catheter in the bladder, the peritoneum is incised in an inverted U incision over the bladder dome following the pelvic arch from the intersection of the pubic ramus and obliterated umbilical vessels to the same spot on the contralateral side. The pubic bone is exposed, and the avascular retropubic space of Retzius is entered to mobilize the bladder and open the space widely, taking care to avoid the obturator neurovascular structures laterally and identify the bladder neck, obturator internus muscle, arcus tendineus fasciae pelvis, and pearly white fibromuscular anterior vaginal wall (pubocervical fascia). One of the table-side assistants places a large cervical dilator in the vagina adjacent to the urethra and bladder neck in the same way one would place fingers for an open or laparoscopic dissection while the second table-side assistant retracts the fatty tissue and bladder medially. Venous bleeders are coagulated with the fenestrated bipolar, and monopolar shears are used for the dissection. A double purchase of 0-Dacron suture on a CT-2 needle is placed 2 cm lateral to the mid- to proximal urethra over the elevated vaginal dilator and is secured to the cartilaginous periosteum of the pubic bone median raphe (Marshall-Marchetti-Krantz stitch). This is repeated on the opposite side, and the next suture is placed cephalad and lateral to the MMK stitch 2 cm lateral to the urethra-vesicle junction with double purchase and secured to Cooper ligament (Burch stitch). The knots for these sutures are tied using a sliding knot for tensioning to leave a 2- to 3-cm suture bridge (**Fig. 17.38**). Due to the lack of tactile sense, it is easy to fracture the sutures if not tensioned carefully using visual clues. Reperitonealization is optional. IV indigo carmine dye is administered, and cystoscopy is performed with a 70- or 110-degree telescope to confirm that no sutures were placed in the bladder and for assessment of ureteral patency.

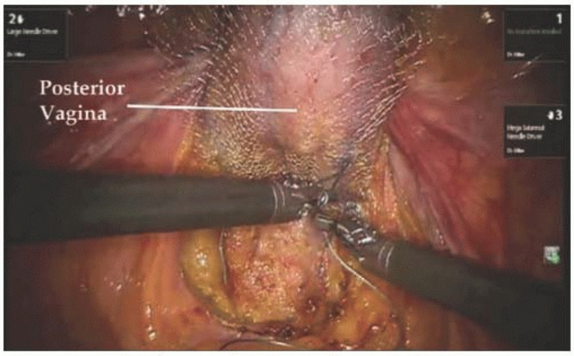

FIGURE 17.36 Mesh secured to posterior vagina.

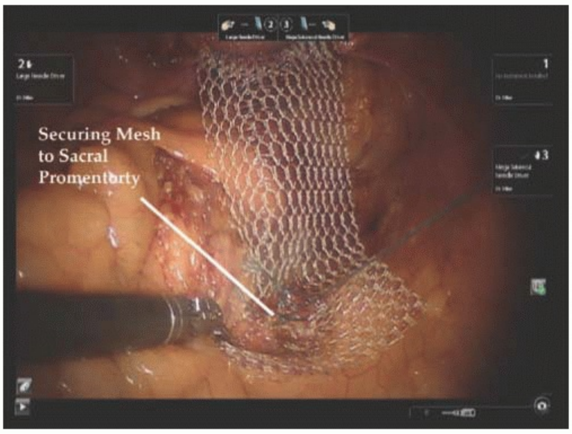

FIGURE 17.37 Mesh secured to sacral promontory.

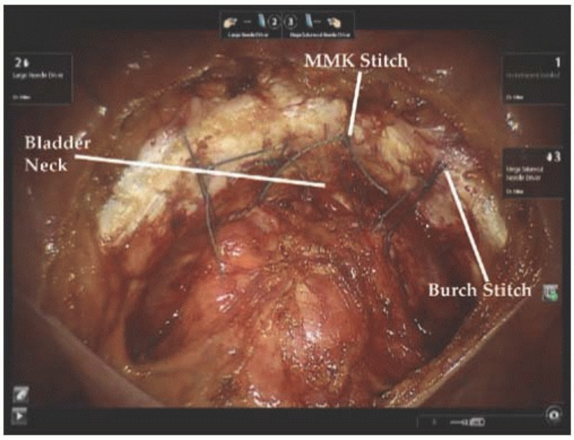

FIGURE 17.38 Placement of Burch and MMK stitches for urethropexy.

Robotic Myomectomy

As with sacrocolpopexy and lymph node dissection, myomectomy is another procedure traditionally performed by laparotomy. Although successfully performed laparoscopically, it is technically challenging with a steep learning curve. The robotic platform has been adapted for this operation.

Table 17.5 lists the five retrospective, observational studies that have evaluated RM compared to open abdominal myomectomy (AM) or laparoscopic myomectomy (LM). Advincula and Nash each compared RM to AM. Both studies found that RM group took considerably longer, especially as the volume of the myomas increased. The RMs resulted in shorter hospital length of stay, but hospital charges were significantly higher, although AM had higher nursing costs. The weight of myomas removed was similar in the study by Advincula, but was lower for RM versus AM in the Nash study. Bedient and Nezhat compared RM to LM. Uterine size, myoma size, and number of myomas in the LM group were greater compared to the RM in the Bedient study but not in the Nezhat study. Barakat and colleagues evaluated RM, LM, and AM. They identified larger myoma weights in the RM group compared to LM, but they detected slightly smaller weights than those removed in the AM group. Overall, these studies seem to indicate that at least in the early stages of RM, operating times are longer with less blood loss and shorter length of stay. Complications and conversion to laparotomy do not appear to be increased. There are no long-term pregnancy data, and cost for RM is higher.

Surgical Technique

The initial technical aspects are similar to preparation for hysterectomy as described previously. Either a straight or side dock technique is utilized. Depending on uterine volume and size, the 8-mm port sites should be placed higher and more lateral if possible for larger myomatous uteri. The surgical principles are the same as for open AM and LM. As described by Frick and Falcone, an intrauterine catheter may be placed to instill indigo carmine dye to detect if there is entry into the endometrial cavity during dissection. Vasopressin is injected either directly through the abdominal wall or via an accessory port into the myometrium for initial vasoconstriction and hemostasis. A monopolar hook or shears are used to make the incision. It is preferable to utilize one uterine incision for multiple myomas if possible. The tableside assistant provides countertraction on the myoma with a grasper or a single-tooth tenaculum. For this operation, the third robotic operating arm is useful for providing countertraction, stabilization, and retraction during the dissection. Bipolar or Gyrus PK may be required to seal larger vessels. If multiple myomas are removed, they should be counted to ensure they are not lost into the upper abdomen. Once the myomas are enucleated, the myometrium is closed in the usual way with layered reapproximation using either interrupted or running delayed absorbable suture (Vicryl, PDS, or V-Loc barbed suture) to close dead space and minimize hematoma formation. Usually, myomas are reduced and removed by a commercial morcellator.

Additional Robotic Procedures in Gynecology

Magrina and colleagues reported on 85 patients undergoing robotic adnexectomy compared to 91 patients undergoing the same procedure laparoscopically. Blood loss, operating time, length of stay, and complications were similar in both groups with no clear advantage to the robotic approach. Additional gynecologic procedures performed robotically and reported by Magrina, Ramirez, Burnett, and Sundaram include radical trachelectomy, staging for early ovarian cancer, and vesicovaginal fistula repair. Nam and colleagues reported the use of robotic technology applied to single-incision laparoscopic surgery. Without question, the robotic platform will be applied to an increasing number of gynecologic procedures.

TABLE 17.5 Robotic Myomectomy

AUTHORS	SUBJECTS	PROCEDURE	MAX. MYOMA DIAMETER (CM)	WEIGHT OF MYOMAS REMOVED (G)	NO. OF MYOMAS REMOVED	OPERATION TIME (MIN)	EBL (ML)	LOS (DAYS)	CONVERSION TO LAPAROTOMY
Advincula (2007)	29	RM		227.86		231 ± 85	196	1.48	2
	29	AM		223.76		154 ± 43	365	3.62	
Nezhat (2009b)	15	RM	5.1 (4-8.5)	116 (25-350)	3 (1-7)	234 (144-445)	370	1	0
	35	LM	6.4 (3-12)	156 (15-420)	4 (1-21)	203 (95-330)	420	1.05 (1-3)	0
Bedient (2009)	40	RM	4.7 (0.2-14.4)	210 (7-1,076)	2.7 (1-9)	141 (50-277)	100	5	0
	41	LM	7.0 (1.3-13.5)	350 (10-1,316)	6.5 (1-26)	166 (68-315)	250	9 (>2 d LOS)	2
Nash (2011)	27	RM		20-102		184-280	150	0.5-1.2	
	106	AM		57-208		106-158	150	2.3-2.65	
Barakat (2011)	89	RM	7.7	223		181	150	1	
	93	LM	6.7	96.65		155	100	1	
	393	AM	7.5	263		126	200	3	

RM, robotic myomectomy; LM, laparoscopic myomectomy; AM, abdominal myomectomy; EBL, estimated blood loss; LOS, length of stay.

COST ANALYSIS

While robotic surgery may reduce blood loss and length of stay, shorten recovery time compared to laparotomy, and show comparable results to laparoscopic surgery, cost remains the most significant drawback. **Table 17.6** lists results of studies by Holz, Barnett, Bell, Landeen, Jonsdottir, and Sarlos comparing costs among robotic hysterectomy, conventional abdominal hysterectomy, laparoscopic hysterectomy, and vaginal hysterectomy. Three of the studies make comparisons between procedures performed for benign reasons, while the remaining three studies address cost comparisons in the treatment of endometrial cancer. Cost analyses are difficult to interpret on the basis of a high number of variables and variation in how hospital systems attribute expenses and depreciate equipment. Most studies are retrospective and do not collect real-time expenses, which should vary over time. In addition to hospital expenses, estimates of societal expenses such as recovery time and time off work vary greatly. Bell and colleagues compared actual costs and estimated societal costs of robotic hysterectomy, laparoscopic hysterectomy, abdominal hysterectomy, and staging lymphadenectomy in endometrial cancer patients. Robotic surgery costs were significantly less than abdominal hysterectomy and comparable to laparoscopic surgery. When comparing actual costs for robotic surgery to laparoscopic surgery for endometrial cancer, Holz and colleagues found hospital costs to be significantly higher for robotic surgery. The higher costs are mostly attributable to the price of disposable instruments. Societal costs were not included in the calculations.

In a well-publicized review of the billing data of almost 10,000 hysterectomies done at many different hospitals in the United States, Wright et al. reported that the median total cost for robotic hysterectomy was $2,200 more than the cost of a laparoscopic hysterectomy. This study showed that cost did not decrease significantly with increasing surgeon experience. The median total cost (not charges) for a laparoscopic hysterectomy in the United States in 2010 was $6,679, while the cost for a robotic hysterectomy was $8,868. These costs were direct costs for the operative procedure and did not reflect capital costs to purchase the instrumentation or societal costs of patient loss of functionality during recovery.

Using decision modeling to compare costs among robotic, laparoscopic, and open procedures for treatment of endometrial cancer, Barnett and colleagues included societal costs as a component of the calculations. They found laparoscopic surgery to be the least expensive, with robotic surgery less costly than abdominal hysterectomy. The differences in cost would be minimized if disposable equipment costs decreased. When comparing abdominal, laparoscopic, vaginal, and robotic hysterectomy for benign conditions, Jonsdottir and colleagues found vaginal hysterectomy to have the lowest operative cost and robotic surgery to have the highest operative cost. However, when total hospital cost for all four procedures was compared, little difference was noted. As a general summary of cost-effectiveness, the initial purchase and maintenance of robotic equipment cannot be understated. If an increasing number of procedures that previously would have been performed by laparotomy are performed by the minimally invasive robotic approach, shorter hospital stays, fewer complications, and a shorter recovery times would benefit the patient and society. That said, there is currently little proof to support this assumption. Ideally, a large randomized trial comparing surgery performed by laparotomy, laparoscopy, or robotics would give a more precise conclusion. Given the current level of surgeon and patient bias, it is unlikely that being randomized to laparotomy would be acceptable.

TABLE 17.6 Robotic Cost Comparison

		ROBOTIC SURGERY	LAPAROSCOPIC SURGERY	STANDARD LAPAROTOMY	VAGINAL
	SOURCE OF COSTS	HOSPITAL COST	HOSPITAL COST	HOSPITAL COST	HOSPITAL COST
Holz et al. (2010)	Actual costs	5,084 (median)	3,615 (median)		
Barnett et al. (2010)	Decision modeling				
	Societal perspective	11,476	10,128	12,847	
	Hospital perspective and purchase of robot	8,770	6,581	7,009	
	Hospital perspective with existing robot	7,478	6,581	7,009	
Bell et al. (2008)	Actual costs	8,212 (average)	7,569 (average)	12,943 (average)	
Jonsdottir et al. (2011), benign	Actual total costs	11,004 (mean)	12,329 (mean)	12,678 (mean)	11,820 (mean)
	Actual operative costs	10,528 (mean)	7,710 (mean)	6,215 (mean)	4,210 (mean)
Landeen et al. (2011), benign (indirect and direct cost with depreciation)	Actual costs	8,135 (average)	6,900 (average)	7,005 (average)	5,505 (average)
Sarlos et al. (2010), benign	Actual costs	4,067 (average) Euros	2,151 (average) Euros		

IMPLEMENTING A ROBOTIC SURGERY PROGRAM

The decision to start a program in robotic surgery is complex and costly. In some circumstances, the decision is forced, as in the case of communities unable to recruit urologists out of training due to lack of availability of a robot for radical prostatectomy. In other cases, the decision is elective and designed to enhance an existing surgical program. At times, the robotic program is for marketing purposes to attract more patient referrals for the hospital and surgeons: the “build it, and they will come” theory. Regardless of the original reason to start a robotic surgical program, commitment is the essential requirement. Commitment must come from four unified sectors: the hospital or clinic making the financial outlay, a dedicated group of surgeons, the anesthesia department, and the nursing department. Weak or missing commitment from any of the above members will almost guarantee failure. From an institutional standpoint, commitment to the initial purchase, ongoing maintenance, designation of a sufficiently large OR, and willingness to assign designated, competent staff is required. Anesthesiologists and anesthetists are faced with caring for a patient in 30 degrees of Trendelenburg position, without access to patient extremities, and minimal access to a fully padded face. Ventilatory requirements become more challenging as patient size increases and more complex cases are scheduled. Dedicated bedside assistants and circulating nurses are a critical component to assembling an outstanding robotic surgical team because they are committed to perform a sufficient number and variety of robotic cases to acquire skills needed to become increasingly more efficient. Finally, the surgeons must commit to a protracted learning curve, selecting appropriate patients, and to constantly making fine adjustments to enhance the program. The ultimate goal is shifting complex laparotomy cases to minimally invasive robotic cases with improved outcomes, lower complication rates, shorter recovery times, and improved quality of life for the patients.

BEST SURGICAL PRACTICES

- The surgeon considering adding robotic techniques to his or her practice should be committed to a sufficient number and frequency of cases to maintain the newly acquired skills.
- For surgeons unaccustomed to utilizing different energy sources during open or laparoscopic procedures, the robotic platform will be more challenging and potentially associated with a greater risk of injury until adequate experience is acquired.
- Sharp dissection and attention to normal tissue planes rather than blunt dissection will result in better visibility and reduced bleeding and trauma.
- Patient selection, optimal positioning of the patient on the operating table, and correct positioning of the uterine manipulator will minimize surgeon frustration.
- Vaginal cuff dehiscence can be minimized by extending the bladder dissection off the anterior vagina, avoiding excessive thermal damage to the vaginal incision, placing sutures well back from the vaginal incision, minimizing tension on the vaginal cuff closure, and stressing to the patient the importance of avoiding sexual intercourse for at least *6* weeks following surgery.
- Set the expectations for early dismissal and rapid return to normal activity when robotic surgery is proposed.
- Insist on developing an efficient, competent, and committed surgical team.

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