15 Instrumentation, Platforms, and Basic Principles of Robotics

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Improvements in robotic surgical technology have refined the surgical devices and instrumentation, revolutionizing the approach to gynecologic surgery by overcoming the limitations of conventional laparoscopy. The advantages of robotic surgery over conventional laparoscopy have resulted in a more commonly adopted procedure by which gynecologic surgeons can treat patients. Advantages include three-dimensional optics, increased precision and dexterity, and ergonomic advantages for the surgeon that result in less muscle fatigue. The imitations of robotic surgery include the cost, training requirements, and lack of data supporting its efficacy. To increase the success of a robotic procedure, a variety of factors must be taken into account that include the platform being utilized, the appropriate selection and availability of instrumentation, and patient and procedural considerations. This chapter discusses these factors and the basic principles of robotic surgery.

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P.F. Escobar, T. Falcone (eds.), *Atlas of Single-Port, Laparoscopic, and Robotic Surgery*,
DOI 10.1007/978-1-4614-6840-0_15, © Springer Science+Business Media New York 2014

15.1 Introduction

In recent years, robotic surgical technology has arguably revolutionized the approach to gynecologic surgery. It was largely developed to overcome the limitations of conventional laparoscopy, which include two-dimensional visualization, incomplete articulation of instruments, and limited ergonomics [1]. Since its approval for use in gynecologic surgery by the United States Food and Drug Administration in 2005, the da Vinci Surgical System platform (Intuitive Surgical, Inc.; Sunnyvale, CA) has been widely adopted by hospitals and gynecologic surgeons [2]. Gradual improvements in the robotic platform have further refined the device and instrumentation, which may result in even more widespread use. There are several purported advantages of robotic surgery over conventional laparoscopy. These include three-dimensional optics, increased precision and dexterity, and ergonomic advantages for the surgeon that result in less muscle fatigue. The limitations of robotic surgery include the cost, training requirements, and lack of Level I data supporting its efficacy and safety [3]. Additionally, the robotic platform is cumbersome to readjust once the robot has been docked and the surgeon is sitting at the console. For this reason, it is important to have a thoughtfully considered set-up for each case that is tailored to the operating room, the patient, and the procedure to be performed. To maximize the chance of a successful robotic procedure, a variety of factors must be considered: the platform being utilized, appropriate selection and availability of instrumentation, and patient and procedural factors. This chapter introduces how these factors influence robotic surgery.

15.2 Basic Set-Up and Instrumentation

The only current manufacturer of robotic surgical platforms for gynecologic surgery in the United States produces the da Vinci Surgical System. The most recent model (da Vinci Si System; Intuitive Surgical, Inc.; Sunnyvale, CA) includes support for high-definition video as well as the capacity to have dual surgeon consoles for training purposes. The platform consists of three major components: the surgeon console, the patient side cart, and the vision cart (Table 15.1, Fig. 15.1). At the surgeon console (Fig. 15.2), the surgeon operates while seated viewing a high definition, three-dimensional image of the pelvis. The surgeon grasps the master controls below the display (Fig. 15.3; this is the figure marked console surgeon and joysticks). The system translates the surgeon's hand and wrist movements into real-time movements of the robotic surgical instruments.

Table 15.1 da Vinci surgical system components

Component	Function
Surgeon console	3-D laparoscopic image projected from patient side cart camera
	Master controls to direct patient side cart instruments
	Foot pedal to adjust camera view
	Foot pedal ("clutch") to switch between first and third robotic arms
	Foot pedals to apply monopolar and bipolar cautery
	Master display to adjust video and audio properties of system
Patient side cart	Motorized cart to position robot
	Robotic camera arm
	Three robotic instrument arms
Vision cart	High-definition monitor of laparoscopic camera
	Image processing software

Fig. 15.1 Robotics console

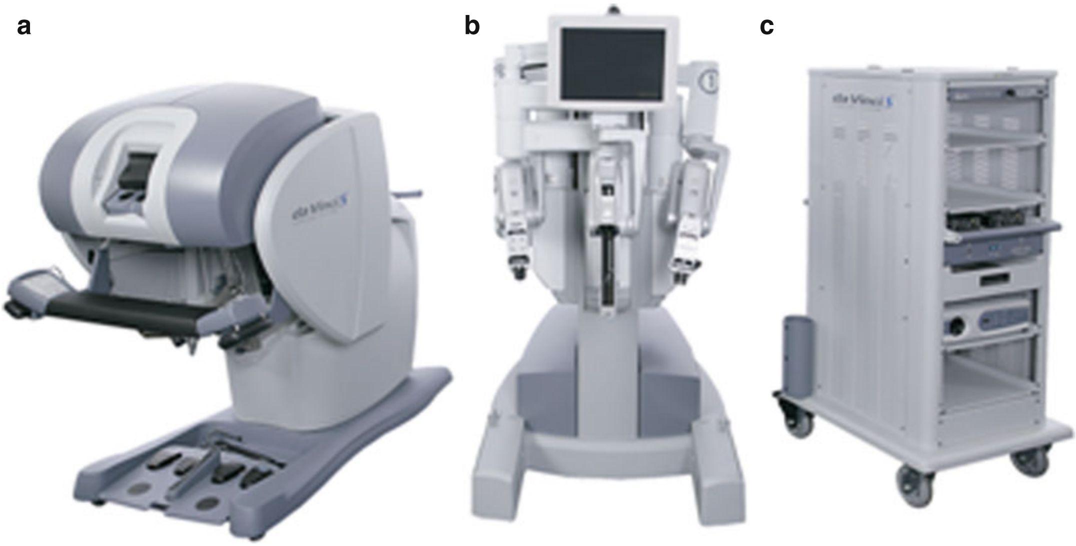

Fig. 15.2 (**a**) Robotic Console (**b**) Robot (**c**) Patient Cart

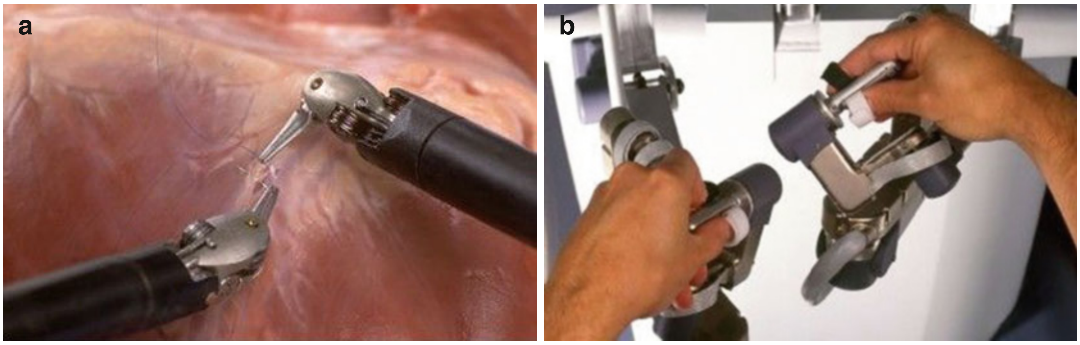

Fig. 15.3 (**a**) Robotic needle drivers (**b**) Robotics console joysticks

The operating room configuration depends on the procedure performed and the layout of the room. The patient side cart is positioned at the bedside during surgery. It includes either three or four robotic arms that respond to the commands of the surgeon at the surgeon console. The robotic arms move around fixed points at the level of the anterior abdominal wall, which may reduce trauma to patient incision sites. For pelvic surgery, at least three operating room configurations have been described: side docking, center docking (between the legs when the patient is in the dorsal lithotomy position), and parallel side docking (Figs. 15.4, 15.5, and 15.6) [4, 5]. If side docking is utilized, the location of monitors, surgical equipment, and the anesthesia staff should be organized to accommodate the patient side cart, which occupies one side of the bed. One possible operating room layout described below easily allows for side docking from the right side of the patient. In this scenario, it is recommended that the bedside surgeon and the accessory port are positioned on the patient's left side. One advantage of side docking versus center docking is that it maximizes assistant access to the perineum/vagina. This allows for greater facility of uterine manipulation and facilitates vaginal delivery of the uterine specimen.

If center docking is preferred, the location of the equipment is flexible and may be organized so that the scrub nurse stands on the same side as the bedside assistant. An advantage of this set- up is that it allows placement of the fourth robotic arm on either side of the patient. In addition, this approach allows robotic trocars to be placed higher in the abdomen without instrument conflict, as may be required in cases with patients with large uteri, for para-aortic lymph node dissection, or for omentectomy in a gynecologic oncology procedure. To obtain better access to the upper abdomen, especially for oncologic procedures, the robot may also be docked from above the head of the patient. This set-up does not allow access to the pelvis and is frequently performed in conjunction with a docking position allowing pelvic access. This approach requires repositioning of both the patient bed and the bedside cart.

Fig. 15.4 Center docking position of the surgical robot

Fig. 15.6 Parallel docking position of the surgical robot

Fig. 15.5 Side docking position of the surgical robot

A variety of EndoWrist instruments (Intuitive Surgical, Inc.; Sunnyvale, CA) are available for robotic gynecologic surgery (Figs. 15.7 and 15.8). The surgeon should limit instrument exchange to improve efficiency and minimize cost. In most cases, the permanent cautery spatula or monopolar curved scissors is utilized in the medial right robotic arm, and fenestrated bipolar forceps or plasma kinetic (PK) dissecting forceps are placed in the left robotic arm. A grasper (ProGrasp forceps; Intuitive Surgical; Sunnyvale, CA, USA) instrument is inserted into the right lateral robotic arm whenever a fourth arm is used. When suturing is required, the medial robotic right instrument is switched for a Mega Suture Cut needle driver (Intuitive Surgical). The left robotic arm is switched to a Mega needle driver (Intuitive Surgical).

Fig. 15.7 Monopolar curved scissors

Fig. 15.8 Maryland bipolar forceps

15.3 Patient Selection

The selection of patients for robotic surgery is similar to the selection of patients for laparoscopic surgery. Most contraindications to robotic surgery are relative and depend on the skill set and experience of the surgeon (Table 15.2) [4]. Patients with decreased pulmonary reserve or poor cardiac function are at increased risk for complications. Patients with decreased pulmonary reserve may not tolerate prolonged ventilation or steep Trendelenburg positions that are required for pelvic robotic surgery. Patients with poor cardiac function may not tolerate prolonged pneumoperitoneum, as this may result in hypotension that may further compromise cardiac function.

The steep Trendelenburg position (30–40°) used during robotic gynecologic surgery plays a role in the tolerance of the procedure. A variety of medical comorbidities may limit patient tolerance of this position, and its judicious use is warranted. Patients are placed in a maximal Trendelenburg position to avoid undocking the robotic arms once the procedure has begun. In some cases, the degree of Trendelenburg positioning required to perform a complex gynecologic robotic-assisted procedure is more than the maximum amount possible on many beds. Surgeons should assess the positioning required at the beginning of the surgery rather than reflexively placing a patient in the maximum amount of Trendelenburg position tolerated. This may allow more patients to tolerate an extended period in this position. Insufflation pressures may also be decreased from the standard 15 mmHg to 10–12 mmHg after initial abdominal entry, as this may also allow more patients to tolerate robotic surgery.

Table 15.2 Relative contraindications to robotic surgery

Possible contraindications to robotic surgery
Contraindications related to patient inability to tolerate Trendelenburg positioning
Arteriovenous malformations (elevated intracranial pressures)
Closed-angle glaucoma (elevated intracranial pressure)
Severe cardiopulmonary disease
Contraindications related to inability to tolerate abdominal insufflation
Severe cardiopulmonary disease
Contraindications related to possible inferior clinical outcomes
Large solid abdominal mass (>15 cm in diameter) precluding laparoscopic removal with morcellation
Suspected metastatic cancer

15.4 Patient Positioning

Patient positioning during gynecologic surgery is an essential step to allow optimal surgical exposure and to prevent neuromuscular injuries. In addition to exposure, correct positioning will maximize range of motion of the robotic arms. The steep Trendelenburg position routinely used during robotic gynecologic surgery may cause the patient to slide in a cephalad direction (owing to gravity) and may result in serious injury. Patient slippage during the fixed portion of the peocedure places lateral tension on the laparoscopic incisions and can cause incisional tears, postoperative hernia formation, and increase postoperative pain owing to overstretching of the abdominal wall. The risk of these occurrences is potentially higher than in conventional laparoscopy because the primary surgeon is not operating at the bedside. Bedside assistants and anesthesia staff should monitor for changes in patient position throughout the procedure to ensure that no slipping has occurred.

To avoid patient slippage during the steep Trendelenburg position, a 3 by 5 foot surgical sheet is placed horizontally in the middle of the surgical table, corresponding to the position of the patient's arms and is later used to tuck the arms. A layer of egg crate foam is placed on top of the sheet and secured to the bed with tape. Upon arrival at the operating room, the patient's occiput should be padded with a gel donut to avoid ischemic necrosis. After the patient is in the supine position and anesthetized under general anesthesia, both arms should be gently tucked in the military position at the patient's side with generous corporeal padding. The legs of the patient should be placed in a dorsal lithotomy position in Allen stirrups (Allen Medical Systems; Acton, MA). Once positioning is complete, a Trendelenburg test may be performed in morbidly obese patients to ensure that they do not slide in a cephalad direction on the bed and are adequately ventilated in this position. Application of Velcro and a thin strip of egg crate foam as a band or cruciate pattern across the chest may also be considered to stabilize the patient and prevent slippage in cases in which the egg crate does not provide adequate support. Attention to patient ventilation should be emphasized if taping is required because the chest wall may become constricted.

Other alternatives to the egg crate include the use of surgical gel pads against the patient's bare skin or the Bean Bag Positioner (AliMed Inc.; Debham, MA). Both devices require disinfection after each case, and allergic reactions are possible. The Bean Bag Positioner is usually fastened to the surgical table and conforms to the shoulders and upper body of the patient. Potential drawbacks of this device include longer set-up time and the possibility of unrecognized deflation of the bean bag during the procedure, causing the patient to slide. The use of shoulder straps, braces, restraints, body straps, or head rests should be discouraged because of the potential risk of brachial plexus injuries.

The arms are tucked using sheets, or in morbidly obese patients with larger arms, sleds may be used. The arms should always be well padded. Overextension, flexion, or abduction of any extremity should be avoided. Adequate padding at all pressure points should be provided. Even though the face of the patient is outside the surgical field, it should be appropriately padded. The robotic camera system can come in close contact with the face and cause facial or ocular trauma. Instruments should not be placed on the face during the procedure.

15.5 Hysterectomy with or Without Salpingo-Oophorectomy

Hysterectomy is the most commonly performed major gynecologic surgical procedure in the United States (Fig. 15.9) [5]. Removal of tubes and ovaries may or may not be included as part of the surgery and should be individualized according to patient needs. The surgical principles and technique of robotic surgery are the same as those for open surgery. The main difference is equipment set-up (Table 15.3), instrumentation, and port placement. The operating room could be configured for side docking or docking between the legs, depending on the surgeon's preference and whether additional procedures are performed. For robotic hysterectomy, location of ports could vary, depending on the indication of the procedure. For benign cases, a 12-mm port is placed either at or above the umbilicus, depending on uterus size. The camera port should be placed at least 8–10 cm above the top of the elevated uterus to allow for adequate visualization and manipulation of the pelvis. In most cases, three robotic trocars are required to complete a hysterectomy. One 8-mm robotic trocar should be placed 2 cm superior to the anterosuperior iliac spine with care to avoid injuring the cecum during insertion. An additional 8-mm robotic trocar should be placed at least 10 cm lateral to the camera port and at least 10 cm away from the lateral trocar. In smaller patients, the robotic trocar may be placed 2 cm to the left of the midline to allow additional space for the two robotic trocars on the right side. One 8-mm robotic trocar should be placed 12 cm to the left of the camera trocar at a 15° downward angle toward the pelvis. An accessory trocar can then be placed in the left upper quadrant equidistant from the camera port and the left robotic trocar. This port is typically 10–12 mm in size to allow introduction of sutures as well as instruments used for retraction, irrigation, suction, or specimen retrieval. Based on surgeon preference, a variety of uterine manipulators can then be placed in order to facilitate the procedure.

Table 15.3 Instrument positioning by gynecologic procedure

Hysterectomy with/without bilateral salpingo-oophorectomy
Arm 1 (right): Monopolar curved scissors or permanent cautery spatula
Arm 2 (left): Fenestrated bipolar forceps or plasma kinetic dissecting forceps
Arm 3 (right): Grasper forceps
15-mm Accessory port in left abdomen: suction and irrigator
Suturing of vaginal cuff
Arm 1 (right): Mega Suture Cut needle driver
Arm 2 (left): Large needle driver
Arm 3 (right): Grasper forceps
Myomectomy
Arm 1 (right): Monopolar curved scissors
Arm 2 (left): Fenestrated bipolar forceps
Arm 3 (right): Grasper forceps
15-mm incision: Morcellator
Suturing of myomectomy defect
Arm 1 (right): Mega Suture Cut needle driver
Arm 2 (left): Mega needle driver
Arm 3 (right): Grasper forceps

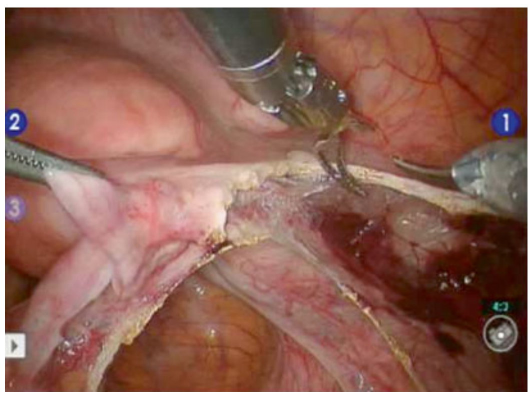

Fig. 15.9 Dissection of the anterior leaf of the broad ligament and vesicouterine peritoneum during a robotic-assisted hysterectomy procedure

15.6 Lymphadenectomy

To perform a lymphadenectomy as part of the gynecologic procedure, the operating room could be configured using any of the previously described docking approaches. For pelvic lymphadenectomy, side docking is preferred. For high para-aortic lymphadenectomy, docking between the legs or above the head of the patient may be considered (see Figs. 15.4, 15.5, and 15.6). Incisions should be placed higher in the abdomen. For example, the camera trocar should be placed approximately 25 cm above the pubic symphysis. The instrument trocars should similarly be placed higher in the abdomen to allow for improved access to the abdomen above the pelvic brim. For most cases, the monopolar curved scissors are placed in the medial right robotic arm, and fenestrated bipolar forceps or PK dissecting forceps are placed in the left robotic arm. A grasper instrument is placed in the robotic fourth arm.

15.7 Ovarian Cystectomy or Salpingo-Oophorectomy

Ovarian cystectomy or salpingo-oophorectomy should be performed laparoscopically in most cases, as these cases are often straightforward and will cost less to perform with conventional laparoscopy compared with robotic surgery [3]. However, indications for robotics-assistance may include anticipated case complexity, endometriosis, or an ovarian mass. Trocar placement is similar to that described for robotic hysterectomy. The trocar placement may vary, depending on the size of the ovarian cyst. Side docking or center docking may be utilized. For ovarian cystectomy, the following instruments are used: monopolar curved scissors in the medial right robotic arm, fenestrated bipolar forceps or Maryland bipolar forceps in the left robotic arm, and grasper forceps in the lateral right robotic arm. A suction and irrigation device can be used in the accessory port. For salpingo-oophorectomy, the following instruments are used: monopolar curved scissors in the medial right robotic arm, and fenestrated bipolar forceps or PK dissecting forceps in the left robotic arm. If a fourth robotic arm is required, grasper forceps can be used. A suction and irrigation device can be used in the accessory port.

15.8 Myomectomy

Robotic-assisted myomectomy should be organized to allow for the use of a laparoscopic morcellating instrument in the accessory port and at least two robotic arms to facilitate laparoscopic suturing. For large myomas extending outside the pelvis, robotic trocars should be placed high enough along the abdominal wall to allow for full range of motion during excision and optimization of the critical view of the uterus and pelvis. During excision, monopolar curved scissors are used in the right robotic arm and fenestrated bipolar forceps in the left robotic arm. A grasper or a robotic tenaculum may be used in the robotic fourth arm if needed. If morcellation is required, the morcellator device can be introduced through one of the accessory trocar incisions after removing the respective trocar. During suturing, the right robotic instrument should be switched to a Mega Suture Cut needle driver and the left robotic arm switched to a Mega needle driver. The use of barbed suture may facilitate efficient closure of the myomectomy defect (Fig. 15.10) [3].

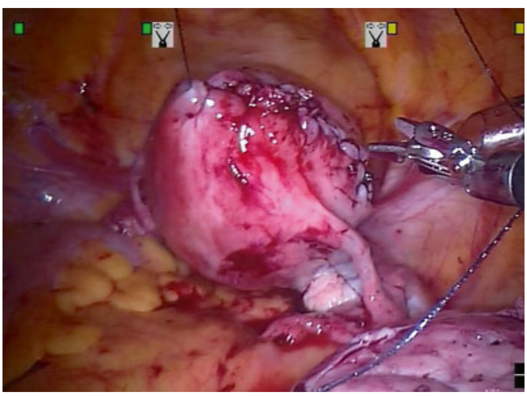

Fig. 15.10 Suturing a uterine defect during a robotic-assisted myomectomy procedure

15.9 Future Directions

Laparoendoscopic single-site surgery (LESS) represents one of the latest innovations in minimally invasive surgery and has several potential applications in gynecologic oncology surgery [6, 7]. It is an evolving surgical approach aimed at further minimizing the invasive nature of surgery. Rather than using multiple incisions, as in traditional or robotic-assisted laparoscopy, procedures are performed through a single, small incision positioned at the base of the umbilicus (Fig. 15.11). Experience using LESS for both benign and malignant gynecologic conditions is rapidly expanding. Recently, the United States Food and Drug Administration approved the robotic single-site platform for cholecystectomy and benign hysterectomy. By operating with pseudoarticulated instrumentation through a single incision and a multiport device in the umbilicus, the platform is compatible with the da Vinci Si robotic system. We await further study to determine the safety, feasibility, and indications for this surgical platform.

Fig. 15.11 Set up and docking of the robotic single-site platform

References

1. Satava RM. Robotic surgery from past to future. Surg Clin North Am. 2003;83:1491–500.
2. Kho RM, Hilger RS, Hentz JG. Robotic hysterectomy: techniques and initial outcomes. Am J Obstet Gynecol. 1997;2007:113.e1–4.
3. Herron DM, Marohn M, SAGES-MIRA Robotic Surgery Consensus Group. A consensus document on robotic surgery. Surg Endosc. 2008; 22:313.
4. Advincula A, Falcone T. Laparoscopic gynecologic robotic surgery. Obstet Gynecol Clin North Am. 2004;31:599–601.
5. Gala RB, Margulies R, Steinberg A, Murphy M, Lukban J, Jeppson P, et al. Systematic review of robotic surgery in gynecology: robotic techniques compared with laparoscopy and laparotomy; Society of gynecologic surgeons systematic review group. J Minim Invasive Gynecol. 2013. pii: S1553–4650(13)01377–0.
6. Fader AN, Rojas-Espaillat L, Ibeanu O, Grumbine FC, Escobar PF. Laparoendoscopic single-site surgery in gynecology: a multi-institutional evaluation. Am J Obstet Gynecol. 2010;203:501.e1–6.
7. Escobar PF, Fader AN, Pariaso M, Kaouk JH, Falcone T. Robotic-assisted laparoendoscopic single-site surgery in gynecology: Initial report and technique. J Minim Invasive Gynecol. 2009;16:589–91.