The Robot

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Abstract

There has been an increase in the use of minimally invasive approaches for many colorectal procedures during the past three decades. Many colorectal surgeons have embraced laparoscopic surgery as their technique of choice for most of the procedures that they perform. It is well known that laparoscopic surgery results in smaller incisions, less postoperative pain, and shorter lengths of stay. Robotic Surgery is an alternative method of performing laparoscopic colon and rectal surgery. Many have suggested that it is the optimal method by which to perform these procedures. This technology has expanded greatly since it was first used for colon and rectal surgery in 2001. Worldwide, the number of robot-assisted procedures that are performed nearly tripled in 2007–2011, from 80,000 to 205,000. We will discuss the most commonly used robotic platform, the advantages and disadvantages of robotic surgery, and the considerations that impact on a successful robotic program at an institution.

Keywords

Robot • Robotic surgery • Minimally invasive surgery • Robotic system • da Vinci • Colorectal surgery • Robotic platform • Vision card • Patient cart

There has been an increase in the use of minimally invasive approaches for many colorectal procedures during the past three decades. Many colorectal surgeons have embraced laparoscopic surgery as their technique of choice for most of the procedures that they perform. It is well known that laparoscopic surgery results in smaller incisions, less postoperative pain, and shorter lengths of stay. Robotic Surgery is an alternative method of performing laparoscopic colon and rectal surgery. Many have suggested that it is the optimal method by which to perform these procedures. This technology has expanded greatly since it was first used for colon and rectal surgery in 2001 [1]. Worldwide, the number of robot-assisted procedures that are performed nearly tripled in 2007–2011, from 80,000 to 205,000 [2].

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We will discuss the most commonly used robotic platform, the advantages and disadvantages of robotic surgery, and the considerations that impact on a successful robotic program at an institution.

3.1 A Guide to the Currently Used Robotic System and Robotic Components

The most frequently used robotic system today is the da Vinci Si (Intuitive Surgical, Inc., Sunnyvale, CA). It consists of a vision cart, a patient cart, and a surgeon console. Firstly, the vision cart (Fig. 3.1) consists of a touch screen monitor; this provides interactive control of video and audio at the patient side and also allows for the ability to draw directly on the screen's endoscopic view, known as telestration. This is particularly useful when trying to point out anatomy to the operating surgeon. The system's core, which is the system's central processing point, is housed in the vision cart. The camera assembly, which provides the three-dimensional, high-definition view, is also part of the vision cart, as is the illuminator, which is the light source for the endoscope. A 0° and 30° endoscope is available; the 30° endoscope can be positioned up or down; this is determined when attaching it to the camera assembly. The three-dimensional image is created by capturing two independent views from 2- to 5-mm endoscopes fitted into the endoscope and then displaying them into two channels which is viewed at the surgeon console's stereo viewer (Fig. 3.2). This provides a three-dimensional, high-definition, bright, and stable image.

The patient cart (Fig. 3.3) is the robotic component that interfaces with the patient directly. It consists of setup joints, which are used to position the arms. There are three instrument arms and one camera arm. The setup joints are connected to the camera and instrument arms, the camera arm holds and manipulates the camera, and the instrument arms do the same for the instruments. The camera arm is what provides the perfectly stable image. Each arm has its own clutch buttons that allow for movements of the arms during docking. Positioning the joints properly is essential to a procedure with the most intra-abdominal reach and the least arm collisions. In general the camera port, target anatomy, and center column of the patient cart should be placed in a straight line, such that the robotic arms are working toward the patient cart. The camera arm joints should be positioned such that the second camera arm joint is opposite arm number three. Also, the camera arm joints should be set up so that it is in its "sweet spot"; the sweet spot is indicated by a thick blue line on joint number two. The blue arrow should be within the boundaries of the thick blue line. This helps to insure that the patient cart is at an appropriate distance from the patient, which will improve arm mobility. Lastly, the camera port, target anatomy, camera port clutch button, third camera arm joint, and patient cart center column should be in a straight line. Exceptions to this exist when side docking; in this case, all other alignment remains true with the exception of the target anatomy which will be 30°–45° from the line created by the other points previously mentioned. The instrument arms should be placed at 45° angles to each other. If care is taken to establish ideal joint position, this will greatly impact on the seamlessness of the procedure. The movement of the patient cart is controlled with the shift switches and the motor drive control. The use of these components must be understood well by the surgeon and the nursing staff because it is essential to docking the robot properly. The patient cart is moved to the patient side using motor drive. This is accomplished by moving the shift switch into the drive position, indicated by the "D." It is recommended that two people be used to move the cart, one to move it and one to direct that person. The throttle-enable switch is held in, and then the throttle is rotated away from you to move forward and toward you to move back. The cart can also be moved in neutral when the shift switch is in the neutral position indicated by the "N" and physically pushing the cart. The shift switch must be on "D" when docking is complete in order to set the breaks. Putting any port in a cannula mount will disable the motor drive and prevent the cart from moving in drive mode.

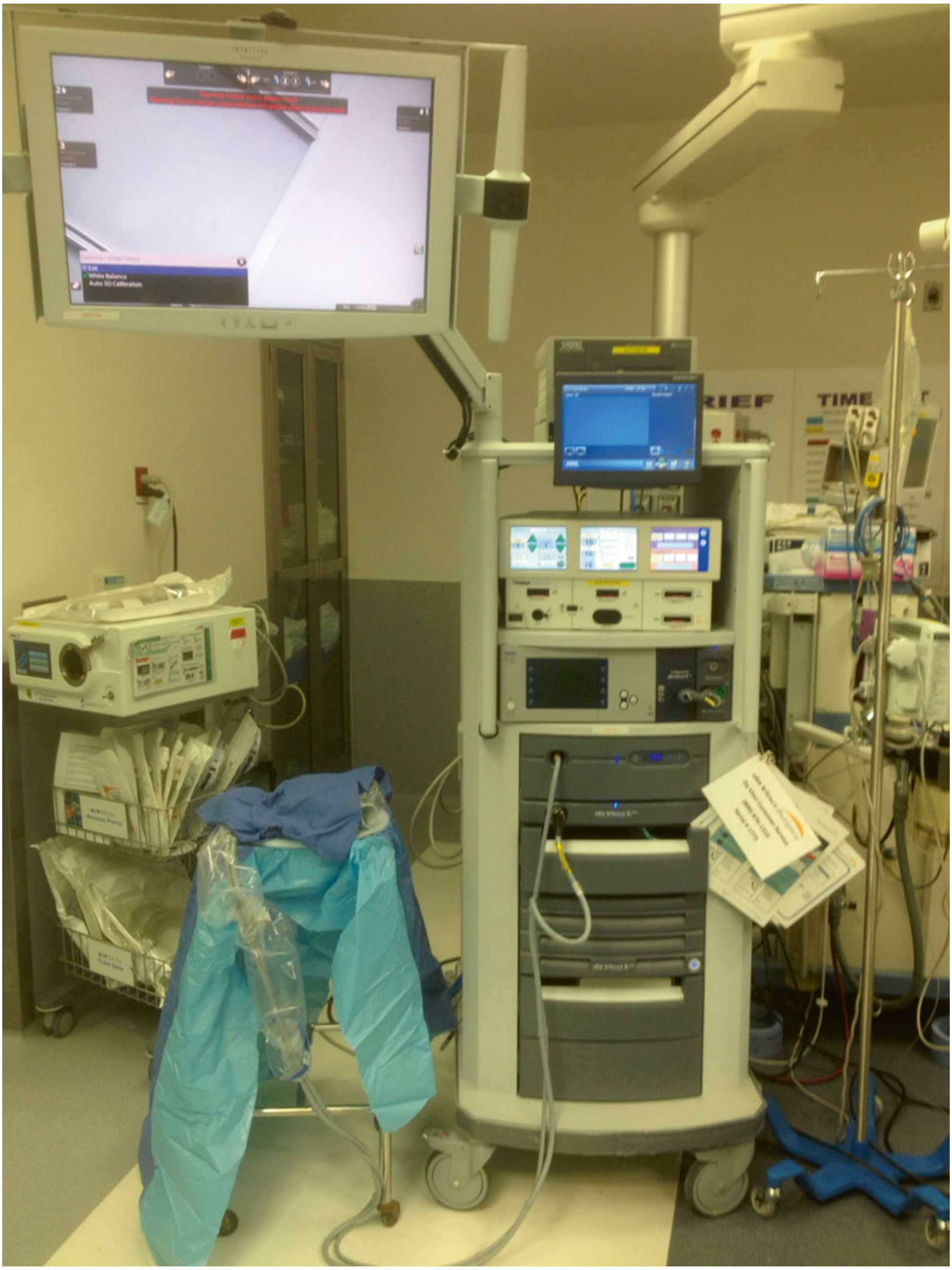

Fig. 3.1 Vision cart

Fig. 3.2 Stereo viewer

The surgeon console is the surgeon's interface with the da Vinci system; it also consists of many components. The stereo viewer provides the three-dimensional, high-definition video feed of the surgical field in real time. It also has a head and neck support for added ergonomic comfort. The stereo viewer also displays detailed messaging and icons that convey system settings for the surgeon during the procedure. These are displayed in specific locations throughout the procedure. The messages alert the surgeon to any changes or errors with the system. Next to the stereo viewer are infrared sensors that activate the surgeon console and robotic instruments when the surgeon's head is against the stereo viewer; the instruments do not move when the head is removed. This prevents inadvertent movement of the instruments. The master controllers (Fig. 3.4) are where the surgeon places his fingers (Fig. 3.5) in order to control the instruments and the endoscope. The master controllers are the surgeon's interface to the EndoWrist instruments, which afford 7 degrees of freedom, 180 degrees of articulation, and 540 degrees of rotation. The master controllers also provide ergonomic comfort and tremor filtration. Movements are simultaneously and seamlessly replicated at the patient cart. The master controllers also have a finger

Fig. 3.3 Patient cart

clutch option, which some surgeons prefer to the foot pedal master clutch. The finger clutch allows for clutching a single master controller without the other, unlike the master clutch foot pedal, which will allow for clutching of both master controllers. The da Vinci Si has 1.5 cubic feet of working space for the master controllers; the surgeon should use the master and finger clutches to establish a comfortable working environment and avoid collisions between the master controllers; this must be constantly adjusted throughout the procedure. The surgeon must also "match grips" by grasping the master controllers to match the position and grip of the EndoWrist instrument tips in the patient's body. This prevents unwanted activation of the instruments and therefore tissue damage. It is advantageous to frequently clutch and keep the master controllers close, to avoid reaching for tissues and avoid surgeon strain. The left-side pod houses the ergonomic control lever; this allows one to adjust the height and tilt of the stereo viewer, move the arm rest up and down, and move the foot switch panel (Fig. 3.6) in and out; these are important for optimal comfort during the procedure. The right-side pod contains the power button and the emergency stop button. The power button will power on the surgeon console (Fig. 3.7) in standalone mode or when

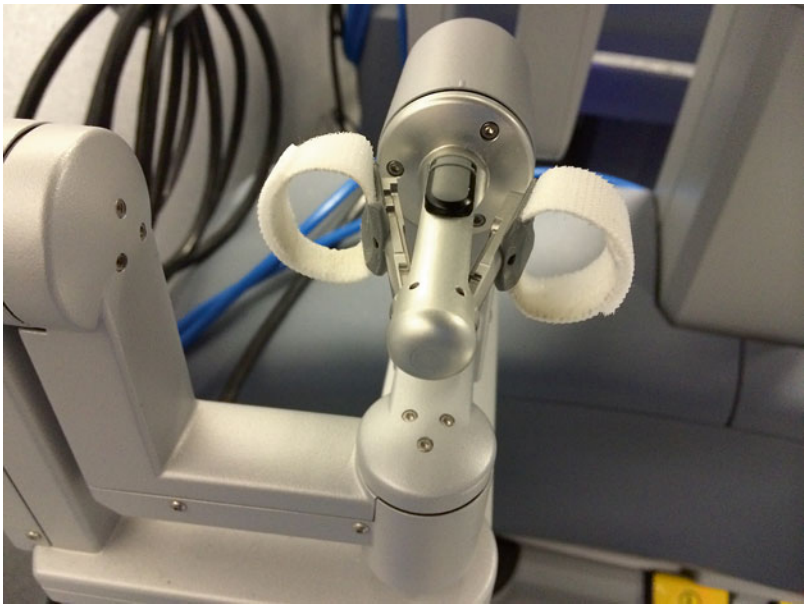

Fig. 3.4 Master controllers

Fig. 3.5 Master controller with surgeon

Fig. 3.6 Foot switch panel

Fig. 3.7 Surgeon console

attached to the other system components can be used to power on the entire system. Pressing the emergency stop button will automatically stop system operation. The touch pad controls the system's audio and video. It acts as the interface for the surgeon to adjust and save personal preferences. The foot switch panel houses the foot pedals. The pedals allow for arm swapping, master clutching, camera control, and integrated instrument activation control. The foot switches are where the actions of many instruments are executed; examples are the energy for monopolar instruments, bipolar instruments, vessel-sealing devices, and the stapler. The Si has two tiers of pedals and a pedal on the side of the panel. On the right side, there are two sets of cut and coagulation pedals, which can control two instruments. The pedal on the side of the panel is for arm switching, and the left-side pedals are for the camera and for master clutching.

There are many EndoWrist instruments available for the da Vinci; we will discuss those most commonly used in colorectal surgery. All instruments have a fixed number of uses; the system automatically tracks the number of uses and will not work if it has exceeded its maximum allowed uses. This information is relayed in the stereo viewer.

The monopolar curved scissors or "Hot Shears" can provide monopolar current. They function like laparoscopic endoshears with the added benefit of being wristed with the typical degrees of freedom described earlier. There are multiple graspers, scissors, and monopolar cautery devices; these are the most commonly used in colon and rectal surgery. The Hot Shears open to 38° and the jaws are 1.3-cm long. The permanent cautery hook is similar to the laparoscopic hook cautery, its hook is 1.6-cm long, and the permanent cautery spatula is 1.7-cm long. The Cadiere forceps are nontraumatic fenestrated graspers; they open 30°, and the jaws are 2.0-cm long; these are appropriate for handling bowel. The Double Fenestrated Grasper opens 60° and is 3.3-cm long; they have a very low closing force and can be used for bowel. The Fenestrated Bipolar Forceps open 45° and are 2.1-cm long and have a medium closing force, but allow for bipolar cautery; they are considered to be the bipolar equivalent to the Cadiere forceps. There are also Maryland Bipolar Forceps; they are curved and fenestrated, open 45° and are 2.1-cm long, and have a medium closing force.

With regard to needle drivers, there are five to choose from; two provide scissors at the base of the jaw. The Large Needle Driver and Large SutureCut are for midsize needles. The Mega Needle Driver and Mega SutureCut are for large needles. And the Black Diamond Micro Forceps are for small needles. All of the instruments mentioned thus far can be used up to ten times. There are also small, medium, and large EndoWrist clip appliers; they can each be used for up to 100 closures.

There are two energy devices available (Fig. 3.8a–p), the HARMONIC ACE Curved Shears and the da Vinci Vessel Sealer, which is similar to the LigaSure in that it is a bipolar energy device. The HARMONIC can be used up to 30 times, and the Vessel Sealer can be used once. There is also a suction/irrigator which can be used once. da Vinci now has an EndoWrist Stapler, which is available in 45-mm length and two staple heights—a blue reload, which is 3.5 mm, and green reload which is 4.3 mm.

The new da Vinci Xi has many features, which are meant to overcome some of the limitations of the previous systems. It is available, but not in broad use as of yet. Many procedures, which require access to multiple quadrants of the abdomen, could not be performed with the da Vinci alone in a single dock. The Xi has thinner arms and instruments with longer reach; also the camera can be placed on any of the arms—these features are meant to make multi-quadrant surgery possible with the da Vinci. The Xi also has voice-guided instructions which makes setup more efficient. There is a laser guidance system that will position a boom, in the appropriate location over the patient to make docking more precise. Lastly, the camera is smaller and lighter (Fig. 3.9a), which is why it can be placed in any arm (Fig. 3.9b), but also allows for better definition and eliminating the need for draping, focusing, white balancing, and calibrating.

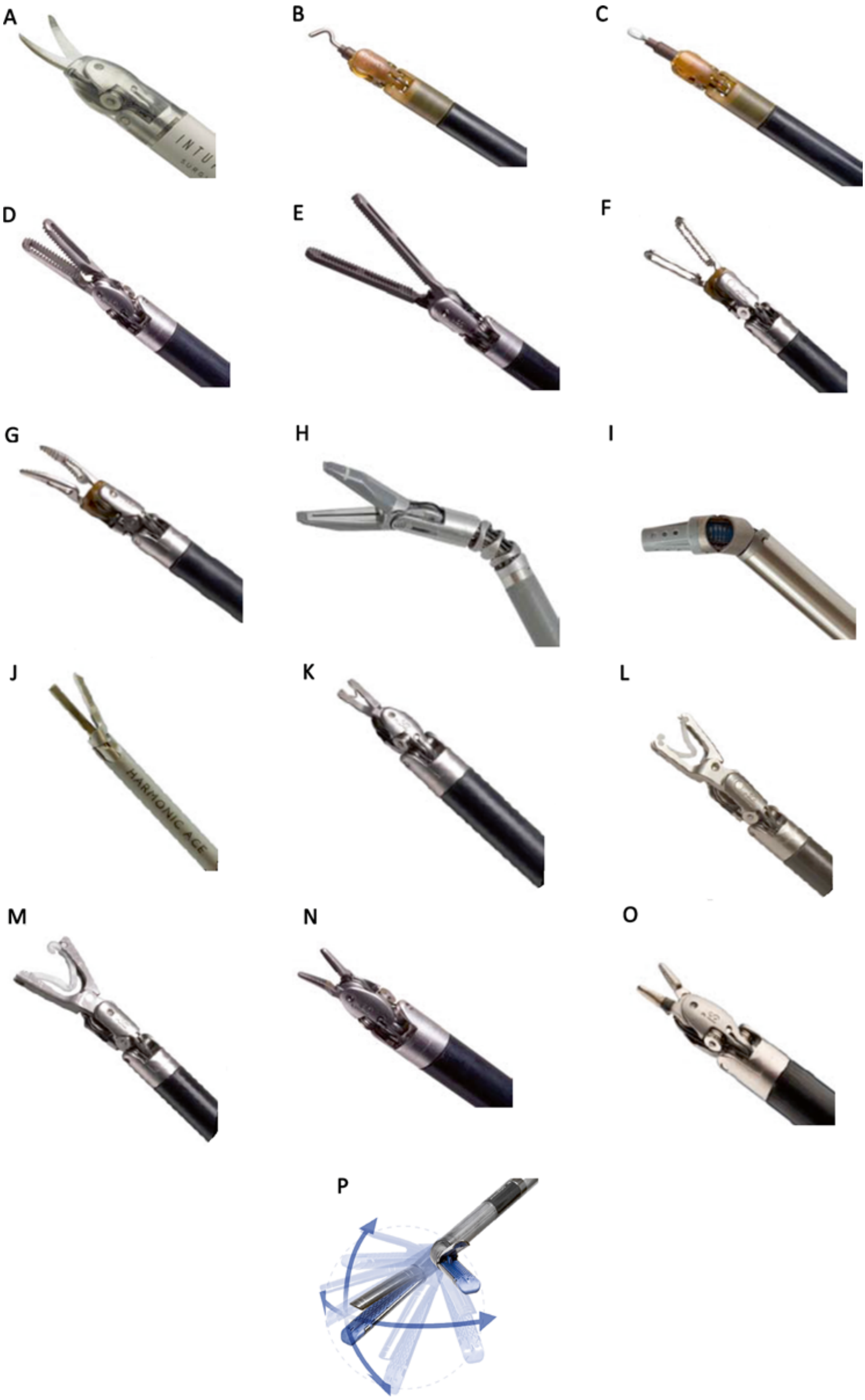

Fig. 3.8 Energy devices. (**a**) Hot Shears. (**b**) Permanent cautery hook. (**c**) Permanent cautery spatula. (**d**) Cadiere forceps. (**e**) Double Fenestrated Grasper. (**f**) Fenestrated Bipolar Forceps. (**g**) Maryland Bipolar Forceps. (**h**) Vessel Sealer. (**i**) Suction/irrigator. (**j**) HARMONIC ACE Curved Shears. (**k**) Small clip applier. (**l**) Medium-large clip applier. (**m**) Large clip applier. (**n**) Large Needle Driver. (**o**) Large SutureCut needle driver. (**p**) Stapler

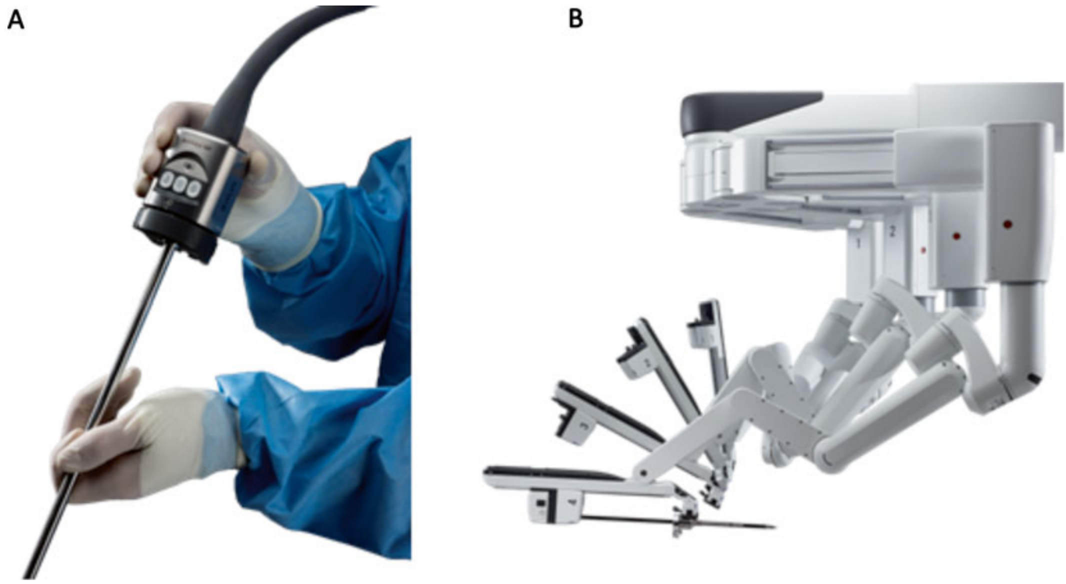

Fig. 3.9 (**a**) da Vinci smaller, lighter camera. (**b**) da Vinci Xi—thinner arms

3.2 Advantages and Disadvantages

One advantage of robotic surgery is the ergonomic position that the surgeon is able to be in during the procedure. This allows for less physical strain and fatigue during the procedure [3]. Also, the improved dexterity of the wristed robotic instruments is a clear advantage. Robotic interface can also downscale movements (5:1–2:1); this combined with the tremor filtering technology makes for a distinct benefit while operating. As discussed, the instruments of a robotic arm have an EndoWrist, which has functions of 7 degrees of freedom, 180 degrees of articulation, and 540 degrees of rotation. Its function is a technological advantage for dissection, especially in small spaces, and intracorporeal suturing. With regard to rectal surgery in particular, there are clear advantages. Robotic approach has particular advantage during pelvic dissection. The surgeon gets equal access to both sides of the pelvis, and the presence of the EndoWrist instruments permits a range of angles to approach the rectum from different directions, thus allowing sharp dissection around the lower part of the rectum and mesorectum [4]. Additionally, the three-dimensional, high-definition, completely stable optics produces superb visualization. Also, the ability for the surgeon to seamlessly control camera position and angle is a definite advantage (Fig. 3.10).

A disadvantage of robotic surgery is the limitation to a single quadrant of the abdomen, which is a significant shortcoming, certainly in colon and rectal surgery [4]. This is one of the reasons that this technique was initially thought of as most beneficial for work in the pelvis. However, many pelvic procedures that are performed require attention to the left upper quadrant as well. This is a concern that is supposedly addressed with the new Xi system. Also the patient cannot be repositioned during the procedure without undocking the robot [4]. For instance, if one would like steeper Trendelenberg or changing to reverse Trendelenberg position, this cannot be accomplished without manipulation of the patient cart and therefore undocking and redocking. Initially, robotic surgery was universally considered to take much longer than traditional laparoscopic surgery; this is no longer thought to be true [5]. In fact, a recent meta-analysis showed that the operative times were not significantly different between the two techniques. Another disadvantage is the lack of haptic feedback. Moreover, suture material can be torn

Fig. 3.10 Surgeon at console

frequently because of no tensile feedback during suturing using the robotic instrument. Also, tissue can be damaged due to lack of tactile feedback. These technological disadvantages can be overcome by learned visual sense, which many robotic surgeons attest to. However, experience is necessary [4]. This learning curve for performing safe and efficient robotic surgery also involves the assistant and the nursing staff. And finally, cost is a major concern. The initial capital investment is substantial, $1–2.5 million [6]. There is also an annual service agreement of which is priced at anywhere from $100,000 to $170,000 [7]. Finally and most significantly, the cost per procedure is also affected by the number of instruments and accessories that have a limited number of uses; this cost is anywhere from $1300–$2200 per procedure. During the first 9 months of 2013, sales of instruments and accessories increased by 18 % and represented 45 % of the company's total revenue [8]. One study showed an increase in operating room costs of approximately $2,000 per procedure [9].

3.3 The Importance of Having a Dedicated Team

It is essential and advantageous to have a dedicated team for robotic colon and rectal surgery. This consists of several components. The nursing staff in the operating room is essential to the success of any surgical procedure; this is especially true in robotic surgery, where there is more instrumentation and need for proper coordination. During a robotic procedure, the surgeon is not operating at the patient's side, but in fact is at a distance from the patient at the surgeon console. Therefore, the surgeon cannot observe the patient or his team members during the procedure. Also, much of the issues with the increased cost of robotic surgery revolve around efficiency and length of the procedure. For both these reasons, having a highly qualified dedicated nursing team is essential for the success of a robotic operation and therefore a robotic program. It has been suggested that a robotic team consist of an experienced, dedicated surgical technician and circulator. It is important that they are familiar with colon and rectal procedures and not simply robotic surgery in general. It is also important to have a managing nurse for the robotic program to oversee the training of new staff and update experienced staff as the program evolves [10]. There should be an ongoing dialogue about the progress of the robotic program at the institution. Initially, monthly meetings are recommended. All meetings regarding the robotic program at the institution should involve the surgeons, the nurse manager, and all members of the team. This is also an essential way to bring up issues as they arise and discuss change as the program grows; these are all aspects that are

Fig. 3.11 Dual console

included in having a dedicated team. Dedicated surgical physician assistants are an asset to any robotic team. Again, due to the remote position of the operating surgeon, an appropriately trained physician assistant can effectively and efficiently accomplish all of the necessary patient side tasks during the procedure. Other options for assistants are less advantageous for many reasons. Having a second surgeon at the bedside in the long run will be costly. Utilizing trainees of any level as the lone assistant is not recommended; she will not be an effective assistant, and the experience will not truly benefit her education either. Training the resident or fellow at the bedside along with a physician assistant present and then also training them at the second console of a dual console (Fig. 3.11) robotic system are a far superior method.

3.4 Partnership with the Hospital Health System in Understanding Program Goals and Financial Support of the Program, Including Dedicated Teams

Likely, the most important element for the success of any new robotic program is the unity of vision between the surgery team and the hospital or health system administration. Of course the goal should always be to provide a better procedure for the patient with better outcomes. However, the path should be agreed upon as well to have the most effective program. Understanding each other's goals, needs, and expectations is necessary from the outset. Because success breeds more success, harnessing the achievements as they come and building upon them are also essential.

There must be a program coordinator; this person can be a healthcare professional such as a nurse, physician assistant, or physician or a non-healthcare professional with the skill and desire to perform all of the necessary tasks. This person will be a link between the administration and the operating room team. She is also responsible for the coordination of the program overall. She should have access to the administrative staff responsible for marketing, patient education, and other avenues of growth for the program [10].

Marketing is certainly part of the success of any new surgical program. In order to offer a new procedure on a large scale, the institution needs to draw patients who require this procedure; this is often patient driven, and therefore, direct patient marketing is necessary; however, marketing to referring physicians is also essential. The marketing team should consist of people who understand the geographical area, referral patterns, and the most effective methods to disseminate information about the new program.

Financial support is essential to the success of the program. Prior to going down the path of establishing a robotic program, the hospital or health system must have a realistic financial plan in place. The capital investment for the purchase of the robotic components and instruments and maintenance is one cost. Also, there is facility renovation to provide an appropriate operating room to perform the procedures. As discussed earlier, a dedicated team is essential; this involves staff retraining and often recruitment of new staff. The administration must often balance this against local payer mix and likely reimbursement for the procedures with the notion that providing a new and desired procedure will increase patient draw, with the appropriate marketing, of course. Additionally, an institution that provides the most up-to-date techniques with good outcomes will likely grow in all of its departments simply due to improved reputation and being considered "cutting edge." However, without the establishment of a realistic financial plan up front, a program is unlikely to flourish.

Ongoing reevaluation of the program's progress is essential. The program coordinator should be constantly evaluating the metrics that make the program successful. These include case volume, docking time, procedure time, conversion rate, complications, and outcomes. It is recommended that a meeting be held monthly that includes the coordinator, the entire robotic team, and all of the robotic surgeons. The data regarding the metrics that are being evaluated should be presented. There should be a discussion regarding the overall health of the program, the obstacles to its development, and new ideas for its growth. There should also be dialogue about the use of resources and the possible need for more resources. Lastly, is the program meeting its goals, should there be an expansion, and are their new applications for robotics that should be evaluated? This periodic assessment will identify any concerns and guarantee that the program continues to provide the best outcomes for our patients.

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