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Single-port Robotic Surgery

Learning Objective: At the conclusion of this continuing medical education activity, the participant will be able to describe key differences between the single-port approach to robotic surgery and the conventional multiport approach, as well as advantages of the single-port approach; implement the single-port platform in their practice in a safe manner, taking into account the learning curve needed to achieve proficiency in the technology; and troubleshoot common problems encountered during single-port surgeries.

This AUA Update aligns with the American Board of Urology Module on Calculus, Laparoscopy-Robotics, and Upper Tract Obstruction. Additional information on this topic can be found in the AUA Core Curriculum section on Laparoscopy and Robotic Surgery.

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KEY WORDS: single-port robotics, SP robot, single-site surgery, minimally invasive surgery

INTRODUCTION

Robotic surgery is an ever-advancing field, with minimally invasive robotic approaches increasingly supplanting open approaches due to decreased overall morbidity, shorter hospital length of stay (LOS), and decreased pain medication needs. Indeed, up to 85% of all radical prostatectomies performed in the United States are now completed via a robotic approach, making the robotic-assisted radical prostatectomy (RARP) the current gold standard nationwide.[1] **The next step in the advancement of minimally invasive surgery came with the 2018 Food and Drug Administration (FDA) approval of the da Vinci single-port (SP) platform, whose uses in robotic laparoscopic single-site surgery are now being explored.** While the platform is currently only available in select centers across the nation, likely due to the technology's newness and the inevitable cost of adopting new technology, there is no doubt that the SP platform will offer a multitude of new approaches for robotic surgeons to add to their armamentarium. In this Update, we review the major differences between the da Vinci SP platform and prior robotic technology, explore patient and case selection, and make suggestions for adopting the SP system and overcoming commonly encountered problems during the learning curve.

DESCRIPTION OF SP PLATFORM

The da Vinci SP system is the fourth-generation platform in the da Vinci series, which previously consisted of the S, Si, and Xi, which were designed to approach patients in a multiport (MP) fashion with multiple small laparoscopic incisions. The SP platform consists of a boom from which 3 fully wristed and elbowed robotic instruments and a fully wristed 12-mm flexible camera emerge (Figure 1). These are designed to be docked via a 2.5-cm SP fixed to an incision that is between 2.5 and 3 cm wide. The instruments can enter body cavities up to 24 cm deep and triangulate at the distal end to minimize clashing. The working field is approximately 10 cm across, with each instrument able to reach 5 cm laterally from midline.

Similarities to prior technology. The SP platform's operative interface and controls for arm and camera movement are the same as previous da Vinci platforms, making transition to the SP system easier for those already familiar with MP controls.[2] Instruments currently available for the SP system will be familiar to experienced MP surgeons and include monopolar instruments, bipolar instruments and graspers, needle drivers, and clip appliers.

Differences from prior technology. **Compared to the MP system, the SP system has a smaller working field, meaning the surgeon tends to work closer to the tissue in SP cases. SP instruments also have lower tissue-gripping capacity, making it more difficult to maintain traction and complete dissections in a single movement. Conversely, the smaller working field makes the SP system uniquely suited for approaches that require navigating tight areas, such as retroperitoneal or transvesical approaches.[3]**

Although the SP controls for camera movement are similar to MP, the SP is unique in that there are 2 different ways to articulate the camera. These movements are activated through the camera pedal foot control and are known respectively as Camera Adjust and Camera Control (Figure 2). Camera Adjust is a fixed articulation that allows the camera to move in and out, right and left, and up and down, similar to a rigid camera. Camera Control, which is activated by an additional clockwise movement of the right hand controller, allows the camera head to move in any direction, similar to a flexible endoscope. It is also possible to activate a special camera setting known as Cobra Mode through a button on the pad screen. This is a special camera setting unique to the SP platform that allows the camera to stay in an ideal position relative to the working instruments, much like its namesake. Finally, the SP boasts a special relocation feature where the boom of the SP robot can move en bloc or rotate 360° around the SP trocar, which serves as a fulcrum. This allows the surgeon to access all 4 abdominal quadrants without needing to change the location of the SP trocar. There is also a virtual navigator on the console that provides real-time monitoring of the relative position of the instruments, which allows for safer repositioning.

Unlike MP cases, true SP cases have less reliance on the bedside assistant due to the limited working space and lack of a separate assistant port. Some institutions will utilize an SP + 1 method where a small 5-mm assistant port is placed near or adjacent to the SP trocar. Additionally, the SP access port has a side port included in the design that allows for laparoscopic instruments to be inserted into the same incision as the robotic instruments (Figure 3). However, instruments are often so close together that tasks traditionally facilitated by

Figure 1. da Vinci SP robotic system. ©2023 Intuitive Surgical Operations, Inc.

ABBREVIATIONS: Food and Drug Administration (FDA), length of stay (LOS), multiport (MP), robotic-assisted radical prostatectomy (RARP), same-day discharge (SDD), single-port (SP)

the bedside assistant in MP cases (such as providing suction or clipping blood vessels) are usually done instead by the operating surgeon.

Why adopt SP technology? There are several potential advantages that the SP robot has over the MP that make it an attractive approach to adopt. Overall, they can be summarized as decreased invasiveness and impact on the patient. **These proposed advantages include improved surgical site cosmesis, decreased postoperative pain, shorter LOS with subsequent cost savings, and equivalent short-term outcomes.**

The lifelong psychosocial impact of scar appearance after major surgery is not well characterized but is clearly an important factor for patients, with one study suggesting that patients favored the concept of scarless surgery even if it were associated with an increase in surgical risk.[4] Having a single small scar is logically more appealing than having multiple. This is supported by a study by Huang et al, which utilized the SCAR-Q questionnaire, a validated tool for evaluating the psychosocial impact of scars on patients, to survey 234 men on their opinions of scars generated by the open, transperitoneal MP, extraperitoneal MP, and SP approaches to RARP.[5] The SP scars scored the highest in both psychosocial impact and cosmetic appearance.

A single-site study of 100 SP robotic cases by Abaza et al in 2021 demonstrated that a large majority (88%) of patients were able to be successfully discharged on the same day as their surgeries.[6] This represented a significant increase in rate of same-day discharge (SDD) for SP procedures compared to MP procedures across all urological procedures performed and irrespective of case order. It was hypothesized in this study that this was possibly due to lower narcotic needs due to a single small incision being less painful, or potentially due to an unintentional bias introduced during preoperative counseling. While a few studies reported equivalent pain scores between SP and MP procedures,[7] many others note a significantly decreased need for narcotics in SP cohorts.[8-11] For example, a propensity score–matched analysis comparing SP to MP simple prostatectomy noted a 50% decrease in postoperative narcotic use for the SP compared to the MP approach.[10] It must be noted that some comparative studies, such as that by Vigneswaran et al,[9] did pool together extraperitoneal and transperitoneal approaches. This represents a potential confounder, as the extraperitoneal approach has been shown to be associated with shorter hospitalization and decreased pain control needs.[12] Nevertheless, the evidence is compelling enough that the Cleveland Clinic was able to successfully implement a nonnarcotic postoperative analgesia pathway in conjunction with SDD for their SP pyeloplasty patients.[11]

Cost is a valid concern for any institution looking to invest in new technology, and the SP is a hefty investment with no shared component with previous da Vinci generations.[13] There currently exists only 1 study comparing the costs associated with the SP platform to the MP at a single institution, which overall found the costs to be comparable for the RARP.[14] The study concluded that, although the SP surgical materials and instruments cost more overall (particularly the cost of disposables, which was 3 times higher for the SP), this was offset by the fact that most SP patients were

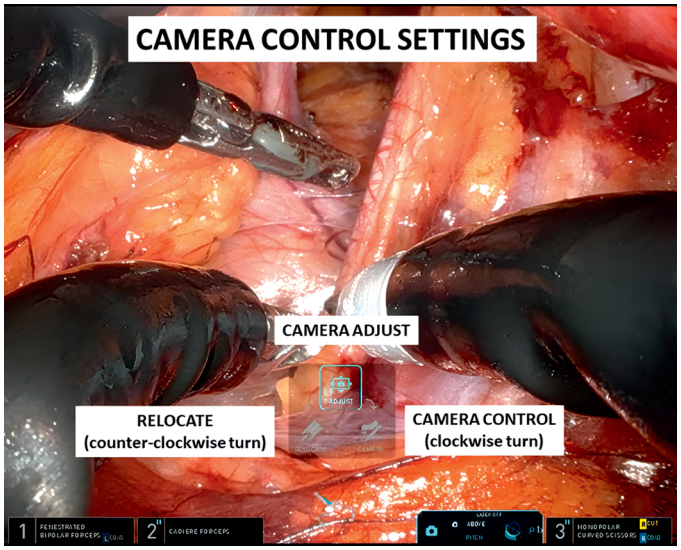


Figure 2. Control settings on the da Vinci SP console for camera movement.

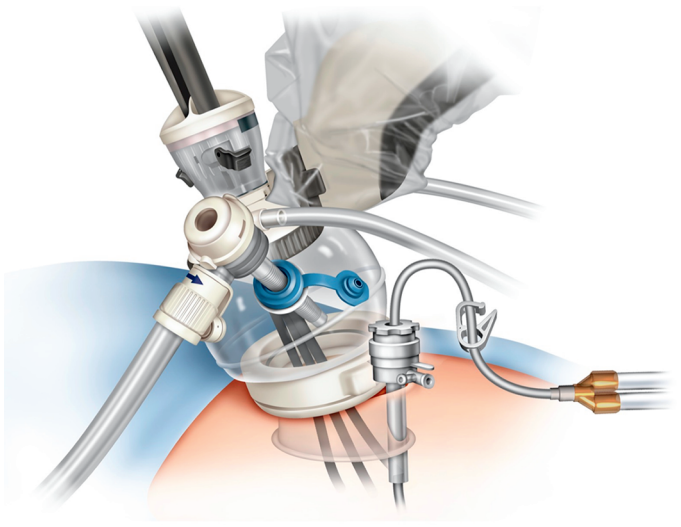


Figure 3. da Vinci SP access port with adjacent assistant port through same incision.

able to be discharged on the same day of surgery, which resulted in a cost savings of thousands of dollars. It may therefore make financial sense to adopt the SP in ambulatory settings where the patient is able to avoid hospitalization entirely.

Short-term outcomes data have overall demonstrated equivalent perioperative and oncologic outcomes between the SP and MP approaches to a variety of cases, including the RARP,[15-20] simple prostatectomy,[21] partial nephrectomy,[22-24] pyeloplasty,[25] radical cystectomy,[26] and adrenalectomy.[27] The RARP is the most common and well-studied SP procedure. A meta-analysis by Bertolo et al synthesized 4 comparative studies on the RARP and demonstrated no significant differences between the SP and MP approaches in terms of operative time, estimated blood loss, complication rate, or positive surgical margins.[15] Another meta-analysis by Li et al compiled 7 studies which concluded that SP and MP approaches had similar perioperative, functional, and oncologic outcomes, with the SP RARP having the advantage of a shorter LOS and catheterization time.[16]

LEARNING CURVE AND ADOPTION OF SP TECHNOLOGY

As with any new technology, the SP platform takes time to master. There is currently no official consensus on the best way to accomplish this. Some studies report the use of dry and wet labs to familiarize users with the SP system, while others suggest observation of more experienced surgeons to start. No studies specifically discuss the need for proctors, which makes sense given that the experts themselves are still in the process of learning and refining new techniques. We summarize some potential strategies to take below.

Learning curve studies. Kim et al note a significant learning curve associated with the initiation of the SP platform due to unfamiliar changes such as the articulation of the SP instruments being at the elbow rather than the wrist, the lack of rigidity of the SP instruments, and the lack of an assistant port.[28] **To shorten the learning curve, they suggest initially completing surgeries via the most familiar approach, which will be transperitoneal for most surgeons.** To avoid microperforation of the peritoneum with the extraperitoneal approach, they recommend entering the preperitoneal space below the arcuate line. **Finally, they recommend placement of an assistant port at the very start of the surgeon's learning curve, which may be removed as the learning curve flattens, a recommendation also employed by Moschovas et al during their learning curve.**[29,30]

A study by Lenfant et al in 2021 used cumulative sum methods to analyze the surgical, oncologic, and functional outcomes of a single surgeon transitioning from MP to SP RARP, from which learning curves were generated. Based on the curve for operative times, they were able to show that the curve could be divided into 4 phases of approximately 30 to 40 cases each, after which the curve reached a plateau, which was taken as a surrogate for surgical mastery. Acceptable levels of complications (10% according to this study) were reached after 30 cases. **Surgeons were shown to approach mastery level after approximately 120 cases.**[31] A limitation of this conclusion is that while a plateau in operative time is reached after 120 cases, this does not necessarily equate to true surgical competence, as faster procedures may not reflect better surgical outcomes.[32]

Another important consideration is the human factor, that is, the interactions and coordinated effort made by the entire operating room team (including surgeons, nursing staff, anesthesia staff, and surgical technicians) to implement this new device. Validated scales for human factor analysis measure a variety of domains, including mental workload, physical workload, communication, situational awareness, frustration, operator fatigue, and performance. Such analyses are critical for the successful implementation of new technologies in a way that reduces errors while maximizing performance. An initial study by Talamini et al found that the cognitive load and mental demands of the SP system were equivalent to the MP, which may reflect familiarity with the console controls.[33] The SP tasks were subjectively found to be more difficult than equivalent tasks with the MP, but were interestingly able to be completed with shorter total operative times, owing perhaps to a consistent and skilled surgical team familiar with the technology. **One takeaway from this study may be that having a dedicated surgical team familiar with the SP robot can help ease the transition when adopting this technology.**

Currently approved cases. According to an FDA review in 2020, the SP platform (specifically the most common model on the market, model SP1098) is "substantially equivalent to the predicate devices" based on bench and cadaver testing, and is currently approved for adult urological cases and a select number of transoral otolaryngological cases.[34] There are numerous descriptions of the use of the SP in other service lines such as general surgery, gynecology, and plastic surgery, though these are typically done in the context of Institutional Review Board–approved trials as the safety of the SP for these has not yet been established. The representative FDA-approved urology cases that were clinically validated based on cadaveric and animal performance testing include the RARP (transabdominal and extraperitoneal), pyeloplasty (transabdominal), radical nephrectomy (retroperitoneal and transabdominal), and partial nephrectomy (retroperitoneal and transabdominal). Many other cases have been successfully demonstrated in the literature, including cases as complex as a radical cystectomy with intracorporeal urinary diversion[35-37] or vaginoplasty with Davydov peritoneal flaps.[38] Technically, any case that is feasible with the MP robotic system is possible to complete with the SP after careful consideration of the limitations of the SP system.

Preclinical studies. The feasibility of the SP platform for many complex urological procedures, such as the cystoprostatectomy with intracorporeal ileal conduit urinary diversion or the perineal, transvesical, and Retzius-sparing approaches to RARP with pelvic lymph node dissection, was first established with preclinical studies on cadaveric models.[39-41] Although these procedures have now been successfully performed and replicated in living patients, institutions with the appropriate resources may still derive value in training first with a cadaveric model. **Bertolo et al published a study in 2018 touting the value of robotic training on cadavers, where 22 residents and 5 supervisors were surveyed before and after a single session of robotic training on fresh-frozen human cadavers and universally endorsed an immediate improvement in resident robotic skills.**[42] **Additionally, cadaveric training was generally felt to be superior to both the da Vinci simulator and training on pigs.** Although this study was done with the MP platform, it is reasonable to assume that the skill improvement would translate to the SP system as well.

OPERATIVE PRINCIPLES AND SP-SPECIFIC CONSIDERATIONS

Preoperative considerations and patient selection. Numerous studies have proven the feasibility and safety of the SP platform for a wide range of urological procedures. Most are small-scale single-center studies, but all report low complications and conversion rates. With the technology being so new, most studies are still in the exploration step of the IDEAL (Idea, Development, Exploration, Assessment, Long-term monitoring) framework for adoption of surgical procedures

described by McCulloch et al in 2009.[43] This being the case, there is no current consensus on the ideal patient to select for SP cases, indications for SP over the MP approach, or long-term complications.

For surgeons at the beginning of their learning curve, a preoperative framework may be developed based on a study by Abaza et al in 2020, where 2 sites employed 2 different strategies for adopting the SP system for RARP.[44] To minimize risk of complication, inclusion criteria included BMI under 30 kg/m^2, no previous abdominal surgery, and lower-risk prostate cancer to avoid pelvic lymph node dissection. One site additionally selected patients with preoperative impotence, as the quality of nerve sparing with the SP approach was as yet uncertain. The operating surgeons were first trained in a cadaver lab setting prior to their first procedure. The first 10 RARP procedures were performed with an MP robot on backup in case of malfunctions or difficulties completing the case with the SP robot. One site completed the procedure with only a single incision, whereas the other added an additional assistant port for suction and retraction. At one site, the postoperative pathway targeted SDD, while at the other site admitted patients overnight. Both approaches were shown to be successful and allow for immediate, safe, and efficacious outcomes in selected patients.

We therefore suggest initially selecting patients with minimal comorbidities, no prior abdominal surgeries, and a BMI under 30 kg/m^2. **Notably, factors such as diabetes, perineal approach, and need for postoperative opioids were shown to be associated with increased rates of postoperative complications, whereas BMI over 30 kg/m^2 was associated with increased hospital readmission.**[45] Other considerations for case selection include avoiding cases with a higher need for traction to start, since the SP platform has a reduced grip capacity compared to the MP system. Given that the incision is 2.5 to 3 cm, one should also consider the size of the specimen to be removed. For example, some SP RARP studies had an additional preoperative exclusion criterion for prostate sizes above 80 g.[46]

Anesthesia requirements and management. All SP robotic cases are performed under general anesthesia. Two important points to keep in mind with respect to anesthesia requirements include patient positioning and intraoperative CO_2 absorption. **It should be noted that unlike the traditional MP transperitoneal RARP, the extraperitoneal SP RARP can be completed with the patient in the supine position rather than in steep Trendelenburg, which eliminates the morbidity and iatrogenic injury associated with this positioning. This approach may be better for patients who are unable to tolerate steep Trendelenburg, such as those with lower pulmonary reserve or morbid obesity.** The extraperitoneal approach is, however, associated with increased CO_2 absorption compared to the transperitoneal approach,[47] which must often be managed with higher minute ventilation. **At our institution, we often keep the baseline insufflation pressure lower in extraperitoneal cases (10 mm Hg) to minimize this effect.**

Postoperative care. As previously mentioned, many SP cases have been found to be associated with a faster overall recovery with decreased opioid needs. It is therefore possible to safely implement a postoperative protocol consisting of SDD and a nonnarcotic analgesia regimen, although, of course, all patients should receive appropriate counseling and preoperative expectation setting**. Patients best suited to opioid-free management include those undergoing a less invasive approach to surgery (extraperitoneal rather than transperitoneal, for example) or with a lower BMI, under 30 (see Video, https://vimeo.com/auaedu/review/809023072/f4a8eae41d).**[48]

INTRAOPERATIVE TROUBLESHOOTING

We list some of the most commonly encountered problems during SP cases at our institution and offer troubleshooting options.

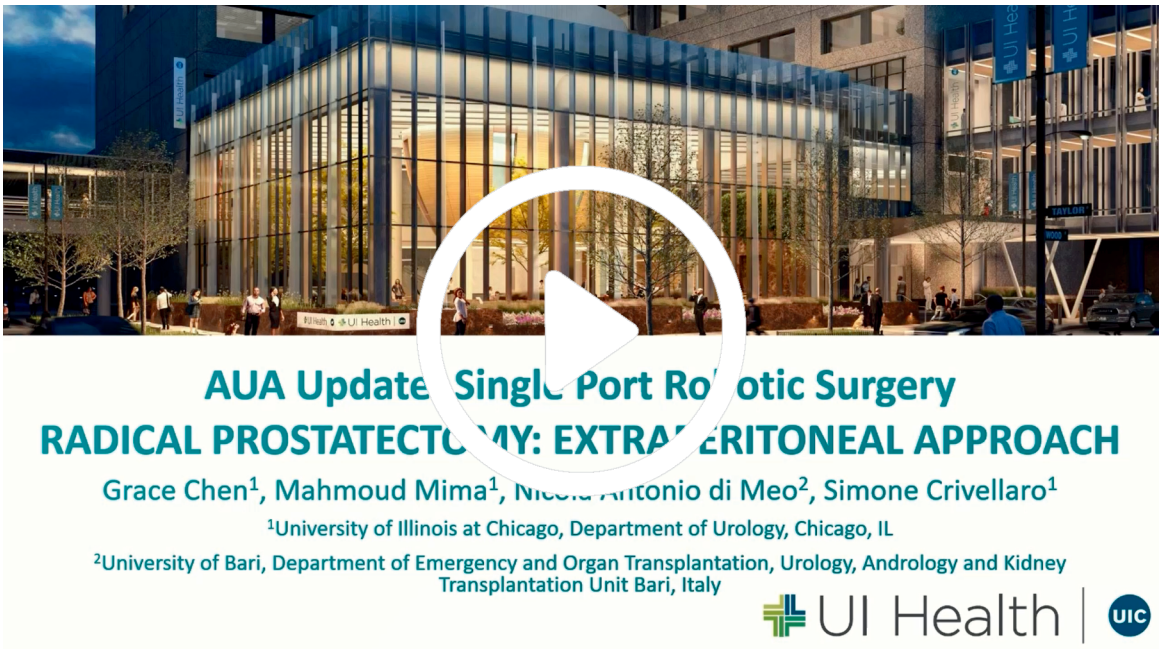
Small working space and narrow field of vision. The field of vision and working space in an SP case will be smaller than in the standard MP case, which makes it imperative for the surgeon to choose the optimal location and angle of entry to maximize the working space and degree of arm mobility during surgery. Even with an ideal entry location, the working space remains smaller than that afforded by an MP approach, a problem which can be overcome with more frequent, small camera movements.

If the tissue of interest is deep and remains out of reach with small adjustments, the novel relocation feature can be utilized. This is especially useful when large shifts in the working field are needed, such as in the case of a nephroureterectomy, where it is important to access both the kidney and the ureterovesical junction, which are in different abdominal quadrants and require different angles of instrument entry. If the tissue of interest is too deep for the instruments to reach, the surgeon may also achieve increased depth of reach by having the bedside assistant manually shift the entire SP trocar into the incision, which brings the instruments closer.

Instruments feel stuck attempting certain movements. Another common problem we encounter is the instruments getting stuck when attempting certain movements, particularly on the lateral edges of the working space. The virtual navigator on the console screen shows not only the locations of the arms relative to each other, but also the limits of the quadrants each instrument may move in. The arms should not be overextended beyond the quadrants–instead, relocation should be utilized to adjust the quadrants of the working field.

It is also important to be mindful of the relative position of the camera to the instruments. If the camera or instruments are at an angle to each other, it can make instrument exchange tricky. We therefore recommend straightening the camera and backing everything up to a neutral position to realign the instruments to the insertion site before attempting to exchange instruments. It may also be necessary to use relocation to realign the trocar and instruments with the incision.

Limited traction of tissue. Traction in SP cases must be held by the operating surgeon due to the limited role of the bedside assistant. Because all instruments enter via an SP, the instrument arms are by design close together, making it tricky to hold broad lateral or anterior traction on tissue. The third arm is useful for holding stationary traction on



Video. Single-port robotic prostatectomy: extraperitoneal approach. Video available at https://auau.auanet.org/US2023-L31.

tissue within the working space while the other 2 arms complete the dissection. Because of the small working space, it is necessary to make more frequent adjustments in the positioning of the camera and instruments to complete dissections in the most efficient way.

Poor arm articulation and range of motion. It is important to note that SP instruments require at least 10 cm of distance between the tip of the trocar and the instrument tip for the instrument to fully articulate within the body cavity (Figure 4). The instruments' range of motion is significantly limited if this amount of space is not available. This particularly poses a problem in tight spaces such as the retroperitoneum. Lenfant et al describe a special floating dock technique which can circumvent this problem.[49] To create a floating dock, the operating surgeon can utilize either the GelPOINT Mini in conjunction with an Alexis O-ring wound retractor or the SP access port, which is designed to have a built-in floating dock. These entry ports allow the SP trocar to be docked up to 10 cm above the skin, which increases the working distance from the tissue of interest and improves articulation of the arms in the surgical space.

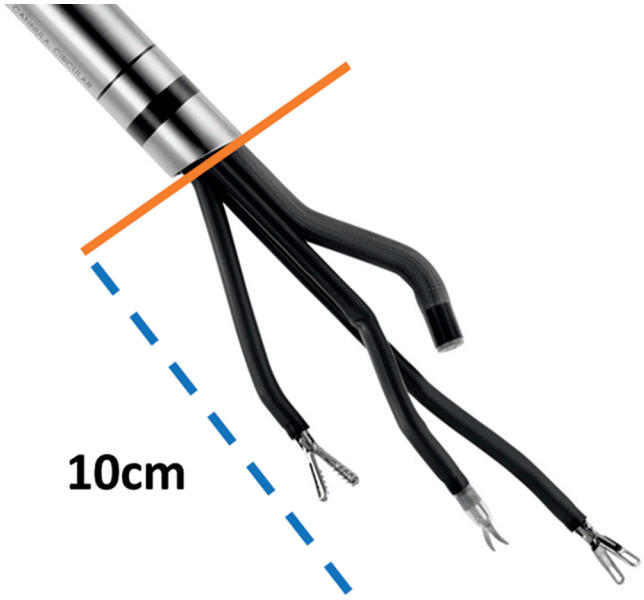


Figure 4. Example of 10-cm requirement for full articulation of da Vinci SP instruments. ©2023 Intuitive Surgical Operations, Inc.

Intraoperative bleeding. The lack of an assistant port in true SP cases means there is usually a limited role for rigid suction for control of intraoperative bleeding. Instead of the rigid suction, many SP cases will utilize a newer flexible suction device known as the Remotely Operated Suction Irrigation device, which may be controlled either by the bedside assistant with a foot switch or by the main operating surgeon via the main da Vinci console. The Remotely Operated Suction Irrigation device can be inserted into a side port within the SP access port and directly into the incision, allowing the surgeon to utilize all 4 apertures of the SP trocar without 1 needing to be taken up by the suction. Flexible suction tends to be less efficient than rigid suction, so it is best to prevent significant intraoperative bleeding in the first place through more frequent use of bipolar cautery when dissecting more vascular tissue.

CONCLUSION

The arrival of the da Vinci SP robotic platform marks a new milestone in the field of minimally invasive surgery. New surgical approaches to traditional procedures are now being explored, and current outcomes are promising, with most studies demonstrating that the SP approach is safe, viable, and able to generate similar outcomes to the well-established MP approach. Assuming the appropriate safety measures are taken during the learning curve, any urologist who is familiar with previous iterations of the da Vinci robot may safely and efficiently adopt this novel technology into their practice.

DID YOU KNOW?

- SP robotic surgery is safe, efficacious, and has largely been shown to have similar perioperative and short-term postoperative outcomes when compared to equivalent MP robotic approaches.
- Advantages of the SP over the MP approach may include improved surgical site cosmesis, decreased postoperative pain, and shorter LOS.
- The SP robot is particularly useful in small surgical spaces, such as the retroperitoneum.
- As with any new technology, there is a learning curve associated with adoption of the SP platform, and several safety measures can be implemented during this learning curve to ease the transition to SP.
- Suggested initial patient selection when implementing the SP includes patients with minimal comorbidities, no prior abdominal surgeries, and BMI lower than 30 kg/m^2.

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Study Questions Volume 42 Lesson 31

1. A 62-year-old man with a history of morbid obesity is undergoing an extraperitoneal radical prostatectomy. When making the initial incision, the location with the smallest risk of microperforation of the peritoneum is the
   a. Preperitoneal space lateral to the rectus abdominis
   b. Preperitoneal space above the arcuate line
   c. Preperitoneal space below the arcuate line
   d. Preperitoneal space medial to the rectus abdominis

2. To improve the safety of procedures at the beginning of the surgeon's learning curve, it is recommended to
   a. Achieve a threshold score of 80% on basic tasks in the SP robotic simulator
   b. Place an assistant port to help with traction
   c. Be observed by an experienced proctor for the first 10 cases
   d. Alternate the surgical team

3. Surgeons adopting the SP were shown to approach mastery level after how many cases?
   a. 30
   b. 60
   c. 120
   d. 180

4. Which of the following factors is noted to be associated with increased hospital readmission following SP radical prostatectomy?
   a. BMI over 30 kg/m^2
   b. Diabetes
   c. Perineal approach
   d. Need for postoperative opioids

5. The patients best suited to opioid-free management following SP robotic radical prostatectomy include those with
   a. Transperitoneal approach
   b. BMI under 30 kg/m^2
   c. No prior abdominal surgeries
   d. Lower-risk prostate cancer