THE DA VINCI SURGICAL SYSTEM AND ITS BENEFITS TO RADICAL PROSTATECTOMIES

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Abstract—“Better visualization, precision and control […] while enabling the surgeon to perform using 1-2 cm incisions” makes robotic-assisted surgeries with the da Vinci Surgical System superior to traditional surgical methods [1]. These technologies of the da Vinci Surgical System make it ideal for radical prostatectomies, which is the removal of the prostate gland after it has been infected with cancerous cells, because of the required precision for this operation. The location of the prostate is what makes prostatectomies such an issue. The major consequences of prostate removal are nerve damage, leading to lack of potency, and urinary incontinence due to the need to cut and reconnect the urethra [2].

Studies from the Italian Department of Public Health in 2010 comparing robotic-assisted versus open radical prostatectomies and factors such as nerve sparing, bladder neck sparing, blood loss and patient health after the operation will be examined[3]. Studies by the Department of Urology at the University of Pennsylvania and the Ghent University Hospital will also be examined to show the growth of the surgery over the past few years [4, 5]. Surgeons still have much to learn with robot-assisted surgeries suggesting that results will only continue to improve. A study by the Vattikuti Urology Institute shows the learning curve analysis for surgeons displays this fact [6]. The positives of the da Vinci Surgical System will ultimately be discussed while refuting data that argues against RARP.

Key Words—da Vinci surgical system, Minimally invasive surgery, Prostate cancer, Prostatectomy, Robot assisted surgery

THE FUTURE OF THE ROBOT SURGEON

Robot-assisted laparoscopic surgery (RALS) is slowly becoming the future of surgical care. With benefits ranging from less pain and blood loss to quicker recovery time and significantly less scarring, robot-assisted surgery is revolutionary and will eventually become the standard in surgical practice [7]. Perhaps the frontrunner in RALS is the da Vinci Surgical System. Created by Intuitive Surgical®, the da Vinci Surgical System has been the face of robot-assisted surgery since its creation in 1999 [1]. The technologies of the da Vinci Surgical System make it ideal for a radical prostatectomy which is the removal of the prostate gland after it has become overtaken with prostate cancer. The da Vinci is beneficial for this procedure due to its precision. Without that level of precision, the patient could be left with lifelong urinary incontinence and impotence. Countless studies show the progressive growth of the information and processes behind radical prostatectomies with robot aid.

Aspects of the da Vinci machine that make it so advantageous are the 3D HD Vision, EndoWrist instrumentation, and minimal invasiveness. These are the features that improve surgeon control and directly affect the potential outcomes of radical prostatectomies [1]. Major problems with prostatectomies are urinary incontinence and impotence, and the effectiveness of robot-assisted radical prostatectomies (RARP) can be measured by time it takes to achieve urinary continence and whether or not the patient once again gains the ability to achieve an erection [2]. Many studies were conducted upon the da Vinci’s initial release which refuted the benefits that it poses. Studies which were conducted by the Italian Department of Public Health, Department of Surgery at the University of Tor Vergata in Rome, Italy, and another by the Department of Urology at Ghent University displayed some of the benefits of the da Vinci as well as some of the shortcomings; however, in recent years, surgeons have learned new techniques of operation such as a new way of reattaching the bladder neck which allows them to become more efficient in using RARP and gives patients better surgical results. This means that the quality of the prostatectomies will only continue to improve [6].

FEATURES OF THE DA VINCI SYSTEM

When crafting the da Vinci Surgical System, Intuitive Surgical® had no intention of replacing the surgeon but rather to enhance him or her. Countless features of the da Vinci make it a superior machine when compared to traditional surgical methods. While many may argue that a middleman between surgeon and patient makes for less control over the surgery and more room for error, the technologies of the da Vinci prove to grant more control over the surgery than there would be without the machine. The system is composed of three or four robotic arms seen in Figure 1 that are controlled by the surgeon, and attached to these arms are tools with one to two centimeter diameters. One of these arms contains a camera allowing the surgeon to see what it is that he or she is doing. The other arms end in EndoWristS that give the surgeon a great deal of control through a very small incision. Through this incision, “The robotic arms move around fixed pivot points which reduces trauma to the patient, improves the cosmetic outcome, and increases overall precision” [1]. The

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surgeon’s movements are also interpreted by a computer, and the movements are scaled. This guarantees that there are no sudden movements from the robot ensuring more control during the operation [1].

**FIGURE 1 [1]**

The *da Vinci* Surgical System robotic components

### Minimal Invasiveness

The main selling point of the *da Vinci* Surgical System is its minimal invasiveness. The surgeon is able to perform procedures through only one to two centimeter incisions [1]. In perspective, this is a little less than the size of a human thumb. A typical robot-assisted radical prostatectomy is done with five incisions around the lower abdominal region. One of these incisions involves the laparoscope, and the other four are the robotic arms [8]. One of these arms allows for water entrance and exit. This allows for areas to be washed of blood and for blood to be sucked up. Near the end of the surgery, this blood suction will allow the surgeons to see if there is any excessive bleeding that needs to be stopped [9]. Surgeons also take advantage of carbon dioxide in order to obtain more movement. The patient’s abdomen is filled with the gas so that he will inflate slightly. This grants the surgeons more room to look and move around [8].

### EndoWrist Instrumentation and Computer Scaling

On the robotic arms are what are called the *EndoWrist*. “Modeled after the human wrist, *EndoWrist* Instruments can offer an even greater range of motion than the human hand, and their internal cables provide maximum responsiveness, allowing [for] rapid and precise suturing, dissection and tissue manipulation” [10]. Unlike the human wrist, however, the *EndoWrist* can rotate a complete 360 degrees which is essential while inside of the body.

The *EndoWrist* can be equipped with many types of instruments that allow the *da Vinci* to perform different functions as needed. These instruments include energy instruments, forceps, needle drivers, retractors, and many other specialized tools. The most useful are perhaps the energy instruments. These tools allow the surgeon to employ cauterization as a mean of cutting by the use of electrical energy, mechanical energy, or lasers. By using these techniques, the energy instruments allow for less bleeding and offer a way of stopping excess bleeding if it were to occur [10]. More and more tools will continue to be developed to fulfill the needs that the different types of surgeries have. Not only are the sizes and functions of the instruments important, but their precision is also paramount. The *EndoWrist* Instruments involve motion scaling and tremor reduction so that any sudden radical movements will not translate to the machine [10].

### 3D HD Vision and Surgeon Console

While inside of the body, the surgeon uses the *da Vinci*’s 3D HD Vision to see what he or she is doing. This grants the surgeon natural depth perception while using the laparoscope inside of the body. Video is sent to the surgeon in high definition and can be magnified up to twelve times. This feature is beneficial in tissue identification so that surrounding and non-cancerous tissues can be left intact minimizing any possible trauma to uninfected tissue [1]. The surgeon will perform the entire operation while seated which can be “clinically advantageous due to reduced surgeon fatigue” [1]. Control over the robotic arms, which are responsible for the main duties of the operation, are done with the surgeon’s hands and feet with the use of the surgeon console seen in Figure 2. Certain ways of moving the controls cause the arms of the robot to rotate, squeeze, and slide. Moving the “joystick-like” controls forward, backward, or side to side will cause the same movements in the robotic arms. With the use of the surgeon’s feet, the laparoscope can be focused, and hand control can be switched from the robotic arms to the laparoscope [11].

**FIGURE 2 [1]**

The surgeon console where the surgeon uses hands and feet to control the robot
BENEFITS VERSUS OPEN PROSTATECTOMIES

Engineers could build the most complex machines imaginable to perform simple tasks, but there would be no purpose unless the machines were more beneficial than the traditional methods in some way. In other words, all of the elaborate technology listed above is great; however, the only logical reason for using such equipment is if the da Vinci holds some benefits compared to open prostatectomies. The benefits of RARP do in fact make the machine worthwhile with benefits ranging from faster healing times, less blood loss, shorter catheter stay, and increased urinary continence and potency. Studies that examined these benefits were done by the Italian Department of Public Health and the Department of Urology at Ghent University. Both show strong evidence of reduced blood loss and retention of urinary continence after the surgery.

Benefits during Operation

Perhaps the immediate benefit to RARP is the entry site. As previously stated, the da Vinci enters the abdomen through five holes which are two centimeters in diameter. On the other hand, open surgeries require an incision five inches long down the abdomen. This incision leads to a much higher risk of infection than the five smaller holes because of the increased incision area. Healing time would also lengthen due to the time needed for the entry site to heal. This would lead to less patient satisfaction. The scarring would also pose as another source of patient dissatisfaction as it would be much larger and more noticeable than the scar left from the robot-assisted surgery. Incision differences can be seen in Figure 3 [8].

The surgeon’s magnification of the operation is also improved. With the 12X magnification granted by the 3D HD Vision, the surgeon has a better view of what he or she is cutting leading to a more precise outcome. With open surgeries, surgeons often rely on a magnifying glass in order to obtain better visualization which typically only magnifies the viewing field by 3X [8].

Use of the da Vinci Surgical System also has a direct correlation to the amount of blood loss that the patient experiences. The average blood loss in RARP was only 116 cc compared to 375 cc with traditional surgeries [8]. According to research done by the Italian Department of Public health, 31.2% of all open prostatectomies experienced severe blood loss compared to only 9.1% of the RARP group. These vast differences are because the incisions required for the da Vinci are so much smaller than the one needed otherwise [3]. RARP was also associated with more nerve sparing with 82% of patients experiencing nerve sparing with the da Vinci compared to only 46% of those without its use [5]. Nerve sparing occurs when the nerves granting a man the ability to obtain an erection are not severed [2]. The fact that there is such a greater number of nerves spared in the RARP patients shows how precise the system is when removing the prostate. Because the prostate gland is so close to this nerve, the utmost care must be given in its removal, and this care is granted with the da Vinci.

Comparison of open surgery (left) and RARP (right) entry sites

Healing Post Surgery

The reduced blood loss and the smaller entry incision leads to faster healing time. In fact, the average hospital stay for RARP patients is only a little over twenty-four hours compared to around forty-eight hours with the open surgeries [8]. Patients must often times remain catheterized even upon leaving the hospital, however. This is because the bladder neck must be given time to properly heal, and because of this, bladder leakage is bound to occur. The length of the catheter stay can tell doctors how well the patient is healing. Patients that were operated on by the da Vinci only remain catheterized for six days on average. This is because of the expedited healing times with the RARP. On the other side of the spectrum, patients that underwent open surgeries remained on a catheter for fourteen days on average. This is more than twice as long as the RARP group [5]. After the catheterization period, men must often wear pads to combat slight bladder leakage. This leakage could persist for up to a year or longer; however, in the radical prostatectomies done by the da Vinci Surgical System, nearly half of the patients are off the pads after only a month. Figure 4 displays information gathered by researchers at the Department of Surgery at the University of Tor Vergata in Rome, Italy, which shows the comparison between the recovery of continence between laparoscopic (that is minimally invasive surgery without the aid of the da Vinci) and RARP. The graph clearly shows that the recovery of continence is much greater in the RARP group [12]. The additional information in Figure 5 gathered at the University of Tor Vergata is perhaps even more convincing. Figure 5 displays the percentage of patients that had recovered erectile function capable for use in sexual
intercourse in patients who had laparoscopic surgery with and without the use of the da Vinci. The graph shows a strong relationship between once again gaining adequate erectile function to perform sexual intercourse and being operated on with the da Vinci Surgical System [12].

**FIGURE 4 [12]**

**RECOVERY OF CONTINENCE**

Graph of continence recovery of laparoscopic versus RARP surgeries

**FIGURE 5 [12]**

**RECOVERY OF CAPABILITY FOR INTERCOURSE**

Graph of erectile function recovery of laparoscopic versus RARP surgeries

**Long Term Benefits**

Long term effects of the University of Tor Vergata study also exhibits the differences between the recovery of erectile functions between both RARP and laparoscopic methods. After one year, 77% of RARP patients gained functional use of their penis for use in sexual intercourse where only 32% did with the laparoscopic procedure [12]. This dramatic difference can be reasoned from the difference in nerve sparing between the two practices. As previously stated, 82% of patients experienced nerve sparing with the da Vinci whereas only 46% were spared nerves in operations without its use [5]. The Ghent University Hospital also gave information on the average period of time that a patient had to meet with his doctor after the operation. After an operation with the da Vinci, patients would meet with their doctor for follow-up examinations periodically for an average of twelve months depending on how well the patient was healing. This compares to follow-ups spanning the length of thirty-one months which was the average period of time for patients that underwent open surgeries [5]. This long stretch of time prevented the patient from fully moving on in life after his prostatectomy where the RARP patients could move on in a much shorter time.

**DISADVANTAGES OF ROBOT-ASSISTED SURGERIES WITH THE DA VINCI**

With every new technology, there are bound to be some technical issues to be resolved. In our example of the da Vinci Surgical System performing radical prostatectomies, there are a handful of reasons why standard techniques may seem superior to the da Vinci; however, these examples are either incorrect on a factual standpoint, or they are easily rebutted by common logic and reasoning. Comments on these inaccuracies will help support the fact that robotic-assisted radical prostatectomies are superior to traditional methods of surgery.

**Expenses**

The first misconception is the overall cost of the da Vinci Surgical System and its comparison to other similar surgeries. The claim has been made that in relation to other ways of performing radical prostatectomies, the da Vinci costs much more in the long run. Yes, it is true that the da Vinci Surgical System has an initial cost that is higher than simply laparoscopic surgeries as it reaches prices greater than one million dollars; however, over time, the costs of using the da Vinci surgical system are reduced due to various factors such as patient stay after surgery [13]. For example, research actually shows that the da Vinci Surgical System reduces hospital stays by almost half and reduces hospital costs by about a third [13]. With this statistic, one could negate this disadvantage entirely because it is just plain false. The price initially is higher, but over time, the hospital or medical center that purchases the da Vinci will gradually make this money back. Also, regarding the high
initial cost of the da Vinci Surgical System, any new technology will cost a lot when first developed, and the price will decrease over time like any other technology.

**Steep Learning Curve**

Another one of the debatable disadvantages to the *da Vinci* Surgical System is the steep learning curve for doctors who wish to use the *da Vinci* robot. A report from Brown University showed that even after the training program surgeons must go through, most surgeons still needed to operate on 12-18 patients before they felt comfortable enough performing the actual procedure with the *da Vinci* [13]. This is a little worrisome, but the fact that it only takes surgeons twelve patients to feel comfortable with a brand new procedure is impressive. This is a relatively new technology and a completely new way of operating on individuals. The fact is that it is going to take time before surgeons really get the hang of this machine, so that does not seem like that big of an issue in regards to the technology. There are new ways of negating this whole issue completely such as the invention of the new *da Vinci* skills simulator [14]. This simulator will help surgeons to learn how to operate the *da Vinci* in less time and will also ensure that they learn the technology better than they have in the past. There is a very steep learning curve that the surgeons must overcome to use this technology; however, the processes for learning how to operate the *da Vinci* Surgical System will continue to improve.

**Size of the da Vinci**

Another disadvantage to the *da Vinci* Surgical System is that its sheer bulk takes up most of the operating room during surgeries. The large size of the robot does not help when you have an already crowded operating room. The large floor-mounted patient side cart limits the surgeon’s access to the patient; however, the robot is essentially the one doing the surgery while the actual surgeon is basically more of an assistant [15]. While their job is still very important in the actual operation, surgeons do not require immediate access to the patient unless there is a severe complication. Adding to this point, the technology is relatively new, meaning that it will soon be improved. One of these improvements to the *da Vinci* is that it could be smaller, have less bulky arms, and have less attachable instruments consequently making the side table smaller. Yes, overcrowding in the operating room is an issue, but the many positives outweigh this one negative of the *da Vinci*.

Steve Wyland, an engineer for Intuitive Surgical®, trains and oversees the operations performed by surgeons using the *da Vinci* Surgical System. When interviewed about the technology, he stated that Intuitive Surgical® has already developed models of the *da Vinci* that are two generations ahead of the one currently being used. This new system, which will not be released for use until after rigorous testing and approval by the FDA, is composed of only one arm that enters the body which then breaks up into three arms while inside of the body. This, while making the surgery even more minimally invasive, also enables the whole unit to be smaller because the entirety of the arms is merged into only one. Operating rooms that were cluttered with the old model of the *da Vinci* will be made more breathable with the newer and smaller model. Steve also stated that when the engineers learn how to design the machine for optimal function, they can then fully focus on making the machine smaller. Size isn’t a concern to engineers while there are still functions of the *da Vinci* that can be improved so that the safety of the patient is increased [16].

**Lack of Tactile Sensation for Surgeon**

A whole different part of surgery that most do not realize is a huge issue with robotic surgery is that surgeons cannot feel the tissue they are operating on, which is a huge issue for those operating with the *da Vinci*. Some surgeons see this as a huge hindering factor because they lose the whole feel of the operation [15]. An argument against this could be that if a surgeon has been used to doing everything by hand for his or her whole life, then he or she cannot be expected to immediately get used to an entirely new way of operating in such a short period of time.

**IMPROVING THE DA VINCI**

Regardless of any drawbacks that the *da Vinci* may have, a great technology is one that evolves to fulfill the needs of the user. The *da Vinci* Surgical System is constantly being upgraded with new *EndoWrist* Instruments, and the surgeons are continually evolving their practices to get the most that they can out of the *da Vinci*. One of these new practices is the bladder neck plication stitch which is responsible for a much greater increase in the overall effectiveness of RARP in both the operation and postoperative stages. A technology like the *da Vinci* Surgical system is so great because not only can the technology be improved by the engineers, but it can also be improved by the surgeons, for they are able to create new methods of performing surgeries to achieve the maximum benefits.

**New EndoWrist Instruments**

The engineers at Intuitive Surgical® “work side-by-side with surgeons to develop new *EndoWrist* Instruments to address new clinical needs” [10]. New attachments are constantly being created in order to benefit both the patient and the surgeon, for the surgeon wants tools to make the surgery easier, and the patient wants tools to make the surgery safer. While the current *da Vinci* setup is
acceptable, there is some room for improvement. Whenever a new type of EndoWrist is to be put on, the whole instrument must be taken off and replaced with a new one. This is a burdensome process because each tool can be up to one and a half feet in length making the replacement of the tool awkward and time consuming considering how often tools must be exchanged. In order to combat this, the instruments should be designed so that only the head must be replaced. Such a change would speed up operation times greatly.

The instruments can also only be reused ten to fifteen times. If the tools were built with more durability in mind, then they could likely last much longer which would attract more buyers as well as lower the operation costs for the patients [11]. Another benefit of making the tools out of a more durable material is that this material could then be recycled and reused into making other useful items that have the potential to benefit society. They could even be recycled so that the working parts could be used on the machine itself by making them into new EndoWrists. By making these tools out of the same type of non-durable metal instead of recycling parts and using the metal for other things, the broken parts are simply being thrown away. Building the parts out of more durable materials could prove to be very beneficial to the future of the da Vinci, for buyers of the machine will be attracted to buying new EndoWrists less often.

**Learning Curve of Surgeons**

As the surgeons get more and more practice with the use of the da Vinci Surgical System, they are becoming more and more efficient at performing the robot-assisted radical prostatectomies. Figure 6 displays the relationship between procedure number and procedure duration. From this graph, the ability of a surgeon's learning ability can be seen. While all three surgeons started off with procedure times of around 450 minutes, they all ended with an average operation time of approximately 200 minutes after 80 surgeries. The graphs even show that the surgeons possessed the potential to decrease to even faster operation times with more experience [6]. The decrease in operation times shows that the surgeons are learning ways to expedite the radical prostatectomies. Not only are they learning to operate more quickly, but they are also operating with more quality. In the Italian hospital study conducted in 2010, only 4.5% of those treated with RARP were spared nerves; however, this percentage was greatly increased in only two years’ time when the Ghent University Hospital reported in 2012 that they had 82% of nerve sparing in the RARP group. This fast increase is likely because the surgeons were learning how to properly use the da Vinci and were learning the best ways to perform radical prostatectomies [3, 5].

**Bladder Neck Plication Stitch**

Perhaps the most profound example of innovation was the introduction of the bladder neck plication stitch into the RARP. A bladder neck plication stitch is simply a new way to reattach the bladder neck to the urethra discovered in the Department of Urology at the University of Pennsylvania. Figure 7 shows what this stitch would look like. The crossing of this stitch leads to a funneling of the urine through the bladder neck which leads to less bladder leakage whenever the stitch begins to heal. This simple technique has proved to be extremely effective. Although without the bladder neck plication stitch the overall continence rate of RARP is very large (over 90%), the addition of this technique leads to a much faster recovery of this continence. In fact, men with the stitch regained total continence almost three and a half weeks faster on average than those men without the stitch [4]. This gives great evidence in how the surgeons were able to discover innovative ways to solve the issue of urinary incontinence after radical prostatectomies. The stitch is said to be easy to learn and easy to perform in practice, and there were not any noted complications in the 334 patients that were in the original study [4].

**FIGURE 6 [6]**

The learning curve of surgeons in the form of procedure number versus operation time

**FIGURE 7 [4]**

The funneling shape of the bladder neck plication stitch
IMPROVING OUTCOMES AND SAVING LIVES

Radical prostatectomies are greatly improved with the addition of the da Vinci Surgical System in the operating room. Due to the minimal invasiveness of the procedure as well as the added precision granted by the machine, the experiences of surgeons and patients are more positive than those procedures performed without the da Vinci. RARP patients experience shorter stays in the hospital after surgery, much less amounts of blood loss, higher urinary continence rates, and regain potency at higher rates than patients who had not been operated on with the da Vinci. Features of the da Vinci that make the technology superior to other methods include the minimal invasiveness, 3D HD Vision and computer scaling. These grant the surgeon the ability to perform the procedure safely and effectively. After the surgery, patients heal much faster than they do with other methods of operation conveying the fact that the da Vinci is not only useful for its benefits during the surgery but also for its benefits post-surgery. As the da Vinci Surgical System continues to advance in its technologies, the results of radical prostatectomies will continue to improve until, one day, urinary incontinence and impotence are a nonexistent risk of the procedure.

REFERENCES


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